Problems in the Identification of Proportional Spacing Typewriting*

Ordway Hilton, M.A., New York, N. Y.

Late in 1940 the International Business Machines Corporation introduced a new style of typewriter—the proportional spacing machines.[1] It had been traditional with all typewriters that each letter on a machine occupied the same horizontal line space. In contrast this new IBM machine was able to write letters of several different widths so that they resembled printed characters. There are narrow letters, such as "i," "t," and "l," which occupy less space than the basic size lower case letters, e. g., "a," "o," "s," "n," while the "m" and "w" are still wider. Most capital letters are broader than their lower case form.

At the time of introduction typewriting identification specialists did not pay a great deal of attention to this new form of typewriter, but in the intervening fifteen years IBM has successfully marketed this product. Today the machine enjoys a growing popularity with the result that the identification of proportional spacing typewriting is a significant and more frequent problem.

Much credit must be given to the International Business Machines Corporation for their promotion of this new ma-

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 1, 1957, Chicago, Illinois.

[1] Correspondence with representatives of IBM has failed to reveal precisely the first date of public usage of a proportional spacing typewriter. According to this correspondence these machines were however released in 1940, but ten typewriters had been field-tested in 1938 and subsequently sold.

chine. Its introduction came on the eve of World War II, and actually it was not until 1946 that there was an opportunity to develop the market. Its mechanism is much more complicated than the standard electric typewriter so that the Executive Model, as the proportional spacing typewriter is known, must be sold at a considerably higher price than standard electric machines. There was a need for special sales technique—a truly distinctive machine which is indicative of importance and success in the business world. One might say that the IBM Executive is the Cadillac of typewriters. In a large measure, therefore, identification problems involving these machines are not apt to be run-of-the-mill.

This typewriter introduces new concepts in the identification problem. Actually, identification rests upon the same criteria as in traditional typewriting questions, but proportional spacing of itself requires new tools, especially in the form of test plates, to examine thoroughly type face alignments. Furthermore, the shaded type faces with which the great majority of these machines are equipped add complications to the identification problem. Of course, the peculiarities of electric typewriting identification are also common to these machines. It is the purpose of this paper to study both the type history of IBM proportional spacing fonts and to consider the special machine identification problems encountered.

For the sake of completeness we should also mention two other machines: The Varityper and the Underwood differential spacing machines. The former is primarily a composing machine for offset printing and is truly proportional spacing; the latter is what might be termed a semi-proportional spacing typewriter. Underwood's machine has been available for less than a year, and sales have undoubtedly been limited. Neither will be discussed further.

What is Proportional Spacing Typewriting?

A proportional spacing typewriter, produced and marketed by the International Business Machines Corporation, is a machine capable of printing automatically letters of four different widths. It can print a capital or small letter mounted on the same type bar, each of which occupies a different

linear space, by simply operating a conventional shift key, while with other characters the two impressions may be of the same width. The various letter widths of both capital and lower case forms tend to simulate printing. Traditional typewriting spacing, usually built on units of either $\frac{1}{10}$ or $\frac{1}{12}$ inch for most domestic machines, was discarded by IBM. Instead they adopted multiples of $\frac{1}{32}$, $\frac{1}{36}$, or $\frac{1}{45}$ inch units for their proportional spacing typewriters.

The various fonts of IBM type use different unit multiples for some of the letters, but for the most part the narrow "f," "i," "j," "l," and "t," are two unit letters, the balance of the small letters with the exception of the "w" and "m," three units, the "w," four, and the "m," five. With capitals the "I" may be two units, the "J" either two or three, the "S" in some fonts three, the balance of the capital letters four with the exception of the "W" and "M" which occupy five. For purposes of tabulation all numerals have been set up to occupy three units, and starting in 1949 the period and comma have occupied the same space. This description is at best a generalization because of the variation between fonts.

Escapement Units

The basic escapement of the first proportional spacing typewriters was $\frac{1}{32}$ inch, and the three original type fonts, Secretarial, Bold Face No. 1, and Modern have this escapement. In 1950 machines were produced with an escapement of $\frac{1}{36}$ inch, Copperplate Gothic and Mid-Century fonts were the first, and in this same year a $\frac{1}{45}$ inch escapement was introduced with Text as the initial font. In the fall of 1956 eight fonts were available using $\frac{1}{32}$ inch escapement and were marketed under the name of Arcadia, Bold Face Italics, Bold Face No. 1, Directory, Documentary, Modern, Secretarial, and Testimonial. Five fonts were available using the $\frac{1}{36}$ inch escapement, Bold Face No. 2, Copperplate Gothic, Heritage, Mid-Century, and Registry. Two fonts, Charter and Text, used an escapement of $\frac{1}{45}$ inch.

Line Spacing

The introduction of the proportional spacing machine did not of itself require any modification of line spacing, and in

fact today all proportional spacing machines can be equipped with a ratchet which will space six lines of typewriting per inch. The suggested spacing, however, for proportional spacing machines is 5.28 lines per inch (29 teeth ratchets) with the exception of the Directory type, the large face of which requires a line spacing of four per inch. Text and Charter, 1/45 inch fonts, are regularly supplied with a 30 teeth ratchet, six lines per inch. The frequent use of line spacing of 5.28 lines per inch means that alignment test plates should be designed on this unit basis in addition to the six lines per inch plates which are more commonly needed in typewriter identification.

Type Fonts

A brief analysis of the various IBM type fonts follows. Examples of each are included in the illustrations. The 1/32 inch escapement fonts will be discussed first followed by the 1/36 inch and 1/45 inch fonts.

1/32 Inch

Secretarial (26) [2]—This 12 point type face was one of the two which in 1940 introduced the proportional spacing machine. There was a time when it was known as Fine Line, but Secretarial has been its official designation for a number of years. It is the only fine line proportional spacing font, and except for the distinctive spacing the design simulates traditional typewriting very closely. All lower case alphabet characters, numerals, the period, and the comma occupy three spaces except "f," "i," "j," "l," and "t," two units each; "w" four; and "m" five. All upper case alphabet characters occupy four units except "I," two, "S" and "J" three, and "M" and "W" five.

There have been several slight changes in type design, the most significant of which is the redesigning of the "g" sometime after 1948 (Figure 1). Originally, the "J" extended below the base line and spaced two units, but around 1947 or

[2] Numerals shown after the name of each font represent IBM's code number.

1948 it was shortened and widened to three units. Prior to 1947 changes had occurred in both the "%" and the "@." The parenthesis and slant have also been shortened somewhat in recent years.

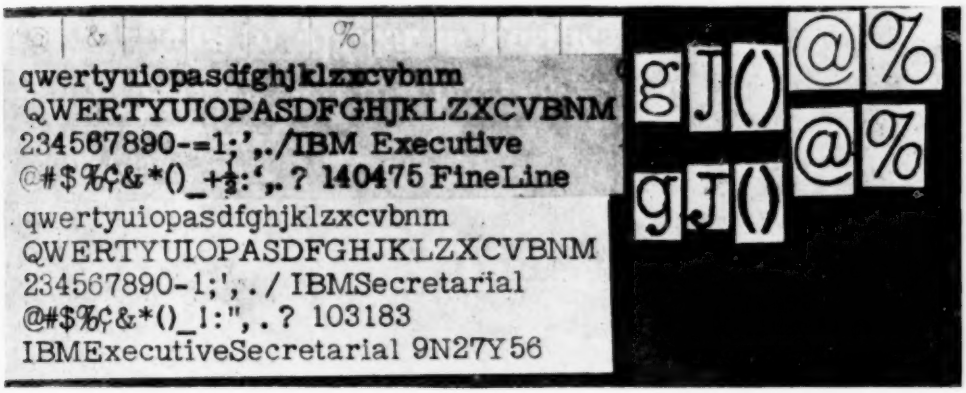


Fig. 1—Secretarial. In this figure and others which follow, the actual specimens are shown to the left and the enlarged key letter changes are shown to the right.

Bold Face No. 1 (16)—Another of the two original 1940 fonts, Bold Face No. 1, had at first the simple designation of Proportional Bold Face, later for a time was known as Proportional Book Type, and finally, by its present designation. It, too, is based on $\frac{1}{32}$ inch units, but is a heavy, shaded, 12 point face, that is not all strokes of letters are the same width. The spacing of individual letters follows exactly the same pattern as Secretarial.

A significant change was made early in the type history of this font when the "J," which originally was two units wide and dropped below the base line, was widened and shortened so that it now spaces three units and rests on the base line (Figure 2). In addition to the "J" change prior to 1948, the "%" and the "@" were also modified and the slant of the "/" was altered a few degrees. Subsequent to the 1948 specimen the base of the "J" was again widened, and the "@" modified once more, and the enclosure of the "P" made

smaller. The current designs of all letters are illustrated in specimen 145573.

Fig. 2—Bold Face #1.

Modern (32)—In 1942 the Modern font was introduced. This distinctive type face has by far been the most popular of the proportional spacing fonts, and today is the one most commonly encountered. It is a 10 point shaded type, and it has a very pleasing design. The faces are slightly smaller, and the printing surface is somewhat lighter than the Bold Face No. 1. Letter spacing follows the same pattern as Secretarial.

There have been basically two changes in Modern type design involving several characters each, but judging by specimens studied these were not made all simultaneously so that each change covers a period of several months (Figures 3, 3A). The earliest font of type is represented by specimen 132615 (old numbering), and changes were gradually intro-

duced in subsequent models until specimen 206923 (old numbering). In all eight lower case letters, "a," "c," "f," "g," "j," "r," "t," and "y," and seven capitals, "B," "E," "F," "J," "L," "Q," and "R," were changed. This same design was carried over into the new model machines, represented by the change of numbering, and with only minor changes, "e," "M," and "J," until the second set of modifications were made after specimen 006360. By the time the serial numbers had reached 31721 the changes appeared to have all been made. This time six lower case letters, "a," "e," "g," "s," "t," and "z," one capital, "M," and five symbols, "@," "%," "( )," and "/" were revised. This is the current font of type, there having been no modifications during the last several years.

Documentary (40)—The Documentary font was IBM's first postwar type, introduced in 1947. It is a shaded 11 point face, and its design resembles in a general way that of Modern. Unit spacing of letters is the same. Actually, upon comparing Modern and Documentary type, one finds Documentary slightly larger or taller than Modern.

The modifications in design of type of this font have been very slight (Figure 4). The bottom of the "Z" was widened after the production of machine 88036 (old numbering), and before machine 00918 of the new (1949) numbering system. Shortly thereafter the "s" was modified by broadening the letter, an early example of which appears in a machine numbered 005216. Prior to 103214 the slant and parentheses were shortened. All of these new designs are shown in a recent specimen, 109271, which is the current font of type.

Bold Face Italics (59)—A rather rarely encountered but highly distinctive type is Bold Face Italics (Figure 5). It was new in January, 1953. All of the letters slant to the right, the 12 point face is shaded, and the design is related to Bold Face No. 1. The unit spacing of letters is the same as the original designs, Secretarial and Bold Face No. 1. To date there have been no type face changes.

Testimonial (71)—In May, 1953, another new font, Testimonial, was added to the $\frac{1}{32}$ inch escapement line. Its 12 point shaded faces gives the impression of a slightly larger type font than any of the earlier designs, and some capital letters utilized a new unit spacing. The lower case letters

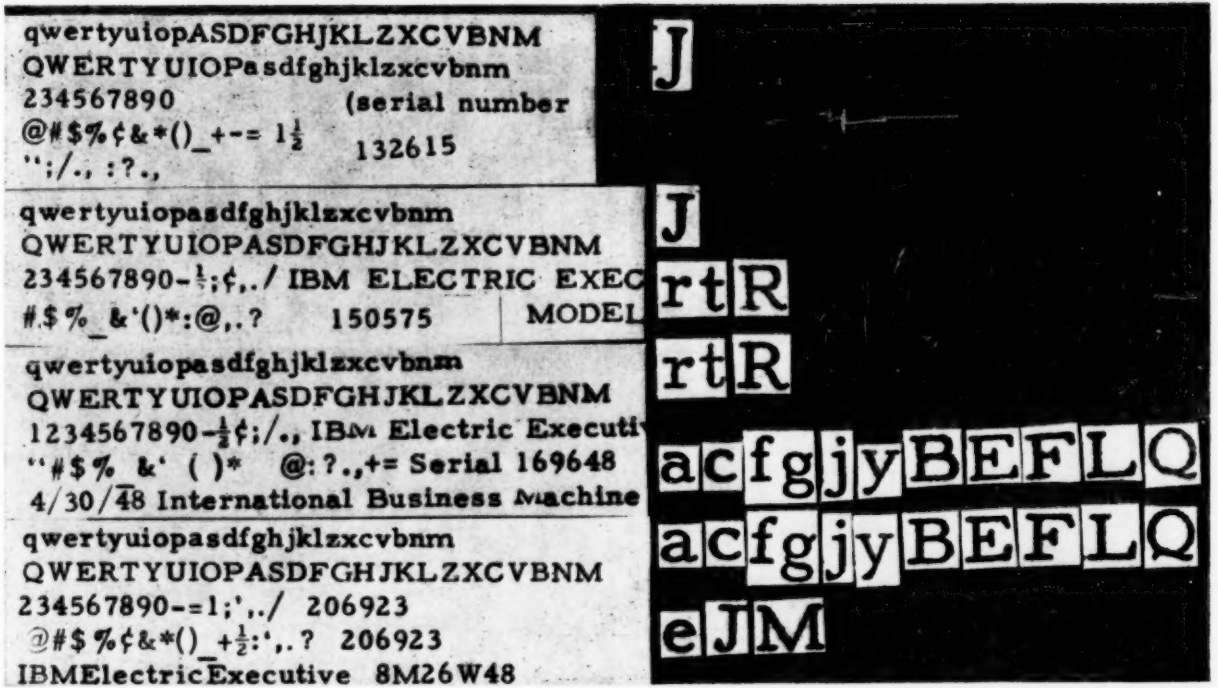

qwertyuiopASDFGHJKLZXCVBNM
QWERTYUIOPasdfghjklzxcvbnm
234567890 (serial number
@#$%¢&*()_+-= 1½
'';/., :?.,
132615
qwertyuiopasdfghjklzxcvbnm
QWERTYUIOPASDFGHJKLZXCVBNM
234567890-½;¢,./ IBM ELECTRIC EXEC
#.$%_&'()*:@,.? 150575
MODEL
qwertyuiopasdfghjklzxcvbnm
QWERTYUIOPASDFGHJKLZXCVBNM
1234567890-½¢;/., IBM Electric Executi
''#$% &' ( )* @:?.,+= Serial 169648
4/30/48 International Business Machine
qwertyuiopasdfghjklzxcvbnm
QWERTYUIOPASDFGHJKLZXCVBNM
234567890-=1;',./ 206923
@#$%¢&*()_+½:',.? 206923
IBMElectricExecutive 8M26W48
J
J
rtR
rtR
acfgjyBEFLQ
acfgjyBEFLQ
eJM

Fig. 3—Modern.

Fig. 3A—Modern.

Fig. 4—Documentary.

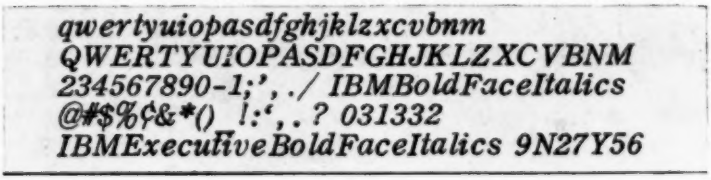


Fig. 5—Bold Face Italics.

space in the traditional way exactly as they do on the earlier fonts, but with the capitals the "J" is narrower (two units) and so are the "B" and "P" (three units). The other capitals agree with the earlier spacing patterns (Figure 6). The only prominent type face changes were the widening of the "r" (November 16, 1953) and possibly "s" from two units to three early in the font's history.[3] The parentheses were also changed.

[3] The present availability of a 2-unit "s," as well as the 2-unit "r," in the Type Available Catalogue suggests that this letter (s) was the original designed spacing. No specimens have been located however. It does not appear on lithographed forms which do contain 4-unit "B" and "P." These forms are usually prepared from "pilot-model" machines several months

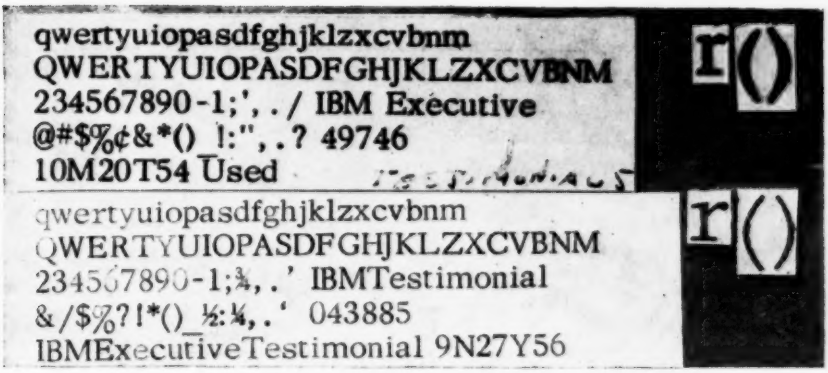


Fig. 6—Testimonial.

Directory (66)—Directory, introduced in June, 1954, is an extremely large face type suitable for use in teleprompter work and for other comparable purposes. The machines are usually equipped with a ratchet spacing of four lines to the inch. The letters are entirely without serifs and are made up of heavy strokes of even width.

The spacing of the small letters does not all follow the more common proportional spacing pattern; the "f," "i," "j," "l," and "t," two units; "h," "n," "u," and "w," four; the "m," five; and the balance of the letters, three (Figure 7). There is also some modification in the capital letters. The "E," "F," "I,"

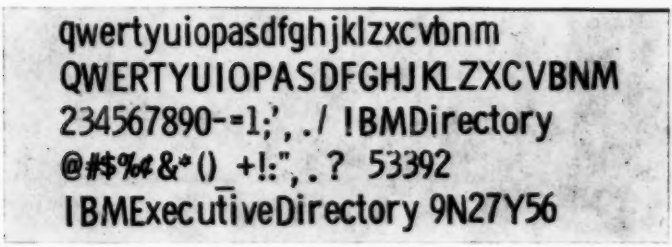


Fig. 7—Directory.

---

before the release date of a new font and may contain letter designs which are not on the first released machines. In the case of the wider "B" and "P," these are now available in optional forms.

The reader should also refer to the Heritage discussion under 1/36 inch escapement in reference to changes from 2-unit to 3-unit "s" and "r."

"J," "L," and "T" occupy three and the "M" and "W," five. The balance of the capitals space four units. The original type face designs are still in use.

Arcadia (79)—Arcadia, new in February, 1955, can best be described as a semi-shaded font. Most of the strokes are uniform in strength, but there are some slight shadings, and the serifs which are heavy tend to be slightly thinner than the more intense strokes. The font is a contemporary design utilizing letter spacing that differs from any other proportional spacing font. All of the small letters are three units except the "f," "i," "j," "l," "r," and "t," two units, the "m" and "w," four. Far more of the capital letters space three units than in any other font. These include "A," "B," "E," "F," "K," "L," "P," "R," "S," "T," "V," "X," "Y," and "Z." The "I" and "J" are two units; the "M" and "W" five; and the balance, four.

There have been two modifications in the type design of this font and both are slight (Figure 8). The most significant one is in the lower enclosure of the "a" which was made smaller between the date of manufacture of specimens 112918 and 125272. During the same period of time the top of the "f" was flattened slightly, but this design of letter had appeared in a very early specimen of this font (039722).

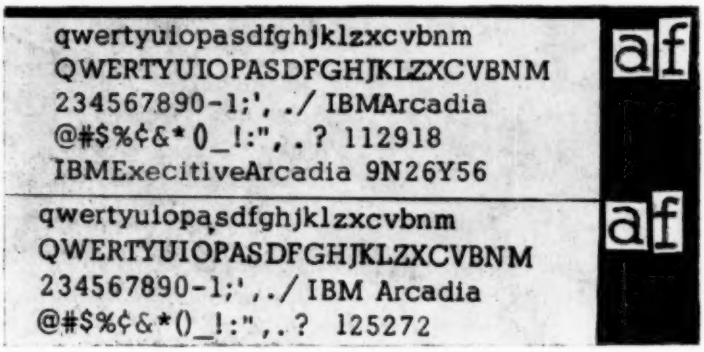


Fig. 8—Arcadia.

1/36 Inch

Copperplate Gothic (46)—The original 1950 font of the 1/36 inch escapement group was Copperplate Gothic, first avail-

able in January. It is primarily designed for photographic reproduction work. The machine actually contains two complete fonts of Gothic type, one 12 point and the other 6 point. All letter forms are capitals. The machine likewise contains numerals in the two sizes.

In the 6 point type, which might be described as the lower case since it types without use of the shift key, alphabetical characters are three units except "I" and "J" which are two and the "M" and "W" which are four (Figure 9). Another unique feature of this machine is that the 6 point numerals occupy two units, as does the period and comma, instead of the usual three.

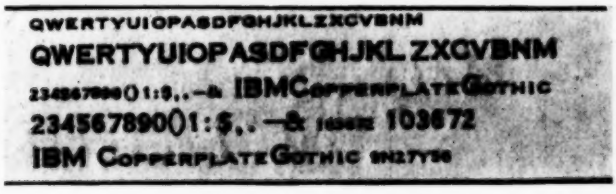


Fig. 9—Copperplate Gothic.

The 12 point type, printed as upper case with the use of the shift key, spaces each letter one unit wider than the corresponding lower case letter with the sole exception of the "I" which occupies two units. The 12 point numerals, period, and comma use three units of space. There has been no change in the design of characters.

Mid-Century (50)—This 12 point type was one of the two initial fonts designed to use an escapement of 1/36 inch and was announced in June, 1950. Characters are without serifs and have a uniform heavy stroke outline. The spacing of the letters is unique. All of the lower case alphabet requires three units except the "f," "i," "j," "l," "r," "s," and "t," two units; and the "w" and "m," four units. The "I" occupies two units, and a great number of the alphabet occupies three, including the "B," "E," "F," "J," "L," "P," "R," "S," and "T." There are more than the usual number of five unit capitals, which include "G," "M," "N," "O," "Q," and "W." The remaining ten capital letters space four units (Figure 10).

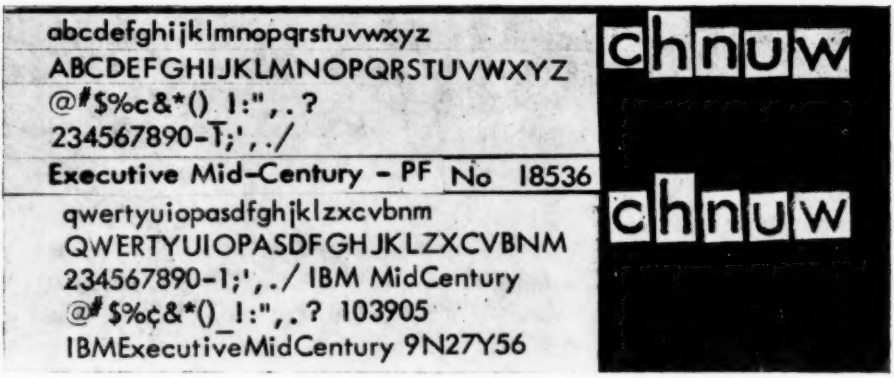


Fig. 10—Mid-Century.

The design of letters in this font have undergone some slight modifications since it was originally introduced.[4] These were introduced prior to machine 37200, and included a slight narrowing of the arch of the "h" and "n," the trough of the "u," and the entire width of the "c" and the "w." (Compare 103905 and 18536.) The symbol "¢" has also been revised.

Bold Face No. 2 (57)—Bold Face No. 2 was introduced in May, 1952. It is the only 1/36 inch font which uses the original letter spacing of the Secretarial and Bold Face No. 1 fonts. The design of type is very similar to Bold Face No. 1, the principal difference being the size of the characters, 10 point.

From a study of these type face designs it would appear that only very slight modifications have occurred and these very early in the type history (Figure 11). The first specimen whose basic serial number is 24058 would from this number appear to be an early Bold Face No. 2 machine. The next specimen available for study bears serial number 43056. By then the lower curve of the "t" as it appears in specimen

[4] Workers are cautioned about accepting for face value the design of type illustrated on certain IBM lithographed forms which illustrate their various proportional spacing type faces. The earlier samples of Mid-Century type is an example of this. Lithographed samples of Mid-Century contain a five unit "m," but this letter had been changed to four units prior to the release of any machines to the public. Standard spacing of this letter is still four units, but the five unit "m" can be obtained upon special order and may occasionally be encountered.

149739 had been adopted; this turns up somewhat more sharply than the original design. The top of the "a" has also been modified. There have been no changes in subsequent years, 149739 being a 1956 machine.

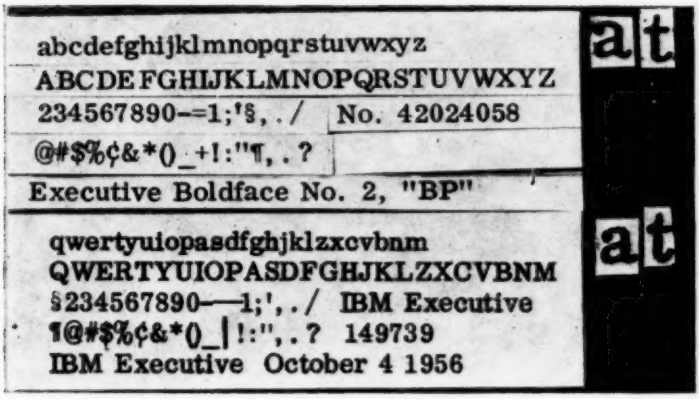


Fig. 11—Bold Face #2.

Heritage (61)—Heritage, released in August, 1952, is closely related in type style to Testimonial; the most significant difference between the letter designs of the two fonts is size. These might be likened to a pica and elite rendition of a similar font of type. All of the letters in Heritage space exactly as they do in Testimonial.

From the best available information there has been some modification in Heritage letter spacing which occurred shortly after its introduction (Figure 12). Specimen 10710 must be one of the first machines available with this font of type. The unit spacing of the "r" and "s" is two units rather than the now standard three. Prior to the manufacture of specimen 39761 the "s" had been widened to its present size, and on November 16, 1953 the "r" was also respaced to three units as appears in specimen 103891.

Registry (65)—In February, 1955, the latest $\frac{1}{36}$ inch escapement font, Registry, was introduced. There is a strong similarity in letter design of this font compared to the $\frac{1}{32}$ inch Directory, but basic differences are encountered over and above that size. The chief of these is found in the numerals,

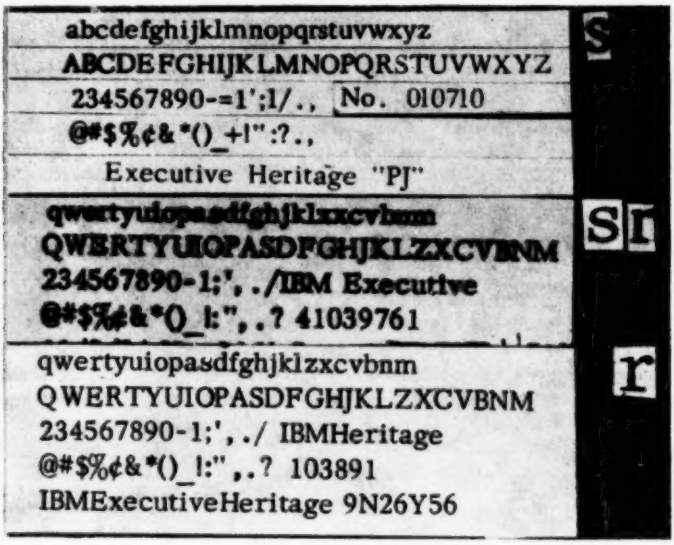


Fig. 12—Heritage.

all of which in Registry occupy four units. A further difference in letter spacing exists between the fonts. In the lower case Registry letters the "f," "i," "j," "l," "r," and "t" require two units of spacing; the "m" and "w," four; and the balance occupy three. Only the "I" spaces two units among the capital letters; the "J," three; and the "W" and "M," five. No modification of character design has appeared (Figure 13).

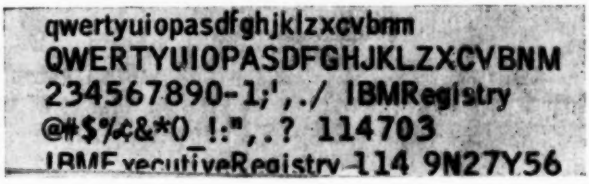


Fig. 13—Registry.

1/45 Inch

Text (47)—In May, 1950, a proportional spacing font of type, Text, was devised utilizing a basic escapement of 1/45 inch. It is a shaded 8 point face. Its letter spacing is unlike

any other proportional font although it is based upon the usual concept of three units for small letters and four for capitals. The exceptions in the lower case letters are "f," "i," "j," "l," "r," "s," and "t," two units; "w," four; and "m," five; and among the capital letters the "I" and "J," two; the "B," "E," "F," "L," "P," "R," and "S," three; and the "M" and "W," five.

One basic change in type design is illustrated which occurred within the last year (Figure 14). (Compare 014295 and 145588).[5] The center stroke of both the "w" and "W" have been dropped, the straight staff of the "h" has been shortened relative to the balance of the letter, and the center stroke of the "E" has also been shortened. The change in the form of the "?" shown in this late specimen apparently occurred earlier in the type history of this font.

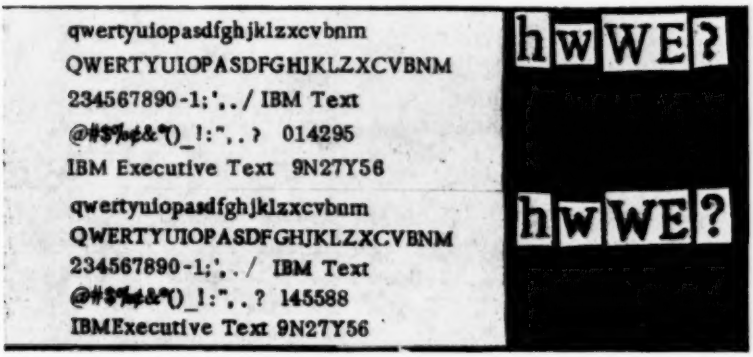


Fig. 14—Text.

Charter (51)—In April, 1951, a second font, Charter, was designed for this narrow escapement. It too is a shaded 8 point type, but there are differences both in letter spacing and design when compared to Text. The small letters, which are basically three units, include eight two unit letters, "f," "i," "j," "l," "r," "s," "t," and "z," one, four units, "w," and one, five, "m." All capital letters are four units except the "I" and

[5] Lithograph forms released by IBM illustrating Text type show slightly different designs of the "a," "k," and "T." From the best information available, none of these three designs have ever been released by IBM.

"J," two units, the "B," "E," "F," "L," "P," "S," and "Z," three units; and the "M" and "W," the usual five units. The specimen illustrated (Figure 15) has current letter designs which have been used since the font was introduced, except for a slight modification in the pumphandle of the "r," February 12, 1953.

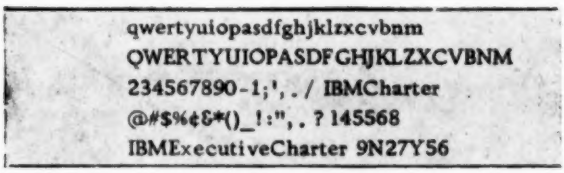


Fig. 15—Charter.

Modification in Spacing

Certain spacing modifications were put into effect with all fonts at or about the same time. The most significant of these undoubtedly was the increased spacing of the period and comma from the original two units to three. IBM reports that these were changed on machines during early 1949, shortly after the new model 14 (change in serial number) was introduced.[6] There is no company documentation of the date of change. In the course of this study two specimens have been located which were typewritten during 1949. Documentary specimen 000918, which is illustrated in an earlier section was prepared in August, 1949, at Milwaukee, Wisconsin. This is the earliest three unit period-comma specimen encountered. The second example was prepared in October. Thus, the latest date of this spacing change can conservatively be taken as mid-1949.

The spacing of the "$" was reduced from the original four units to three. IBM reports that the first machines using the narrower "$" were released in January or February 1950.

[6] Some few Model 14 machines with low serial numbers, probably below 14–000100, have the old two-unit period and comma. This writer has available Modern font, 14–000003, prepared in December 1948, with the two-unit period-comma. These low Model 14 serial numbers are machines especially built to announce the line and incorporated the new mechanical features of the model. Before the Model 14 went into full production in about April 1949 the period-comma spacing appears to have been changed.

The two 1949 specimens which contained the change in period and comma spacing had the old "$" spacing. No early 1950 specimens could be located for the study.

Early specimens of type often contain curved apostrophes and quotation marks, but while these seemed to be more commonly supplied during that period, there has been no definite change of policy on their use, both curved and straight marks were available on Secretarial and Bold Face No. 1 as early as 1942, and IBM currently provides either style for all fonts.

Special Type Faces

The discussion of the previous paragraphs deals only with the usual or "standard" type faces and spacings. Many special combinations can be obtained on IBM machines. These include special spacings of alphabet letters. It is a relatively simple mechanical adjustment to change the spacing of a letter from a particular unit spacing to any other, i. e., two, three, four, or five. The selector bar which controls the escapement spacing is changed by the replacement of a single part and the type form interchanged in the same way as on a standard machine. Several fonts have alternate designs of letters which are supplied upon request and on these machines the standard spacing of the font may be modified. It is not possible within the limitation of available space to even outline these possibilities.

Tools for Identification

One of the chief difficulties in identifying the work of a particular proportional spacing typewriter, or in determining whether material has been added to a typewritten page, is that test plates of standard design are almost useless. Unlike standard pica and elite typewriting, plates cannot be ruled with vertical lines which will define the full areas occupied by each letter by merely using the escapement value. In the previous paragraphs it was pointed out that proportional spacing type varies in width. The only solution is to rule a test plate with vertical lines equal to the unit escapement value, that is $\frac{1}{32}$, $\frac{1}{36}$, and $\frac{1}{45}$ inch. The area of each letter is thereby cut by several of these lines. This writer has had manufactured two such test plates for the $\frac{1}{32}$ and $\frac{1}{36}$ inch

escapements, the machines most commonly encountered in identification work.[7]

These alignment test plates greatly facilitate checking of horizontal alignment of individual characters and recognizing twisted type faces. When unit spacing of a particular letter becomes significant, these plates are also of aid. The slight displacement in horizontal alignment often found in typewriting added after the sheet was taken from the machine is clearly revealed by these rulings.

Proportional spacing typewriters commonly utilize two line spacing units, 5.28 lines per inch and 6 lines per inch.[8] There is need for a test plate ruled horizontally 5.28 lines per inch. The conventional test plates used for ordinary typewriting will handle the 1/6 inch line spacing problems. With Directory type it would be necessary to have a plate with 1/4 inch rulings, but the need for this may not be pressing, for to date this font has not been widely utilized for documents which might be encountered in identification work.[9]

Proportional spacing typewriting does not require an entire new set of instruments. Test plates for measuring the slant of letters need no modification. Other typewriting defects which require visual examination aided by hand magnifiers or the binocular microscope can be handled exactly as they have heretofore. This writer has found, however, that to explore fully malalignment of letters, the vertically ruled test plates are of tremendous value (Figure 16).

Identification of an Individual Machine

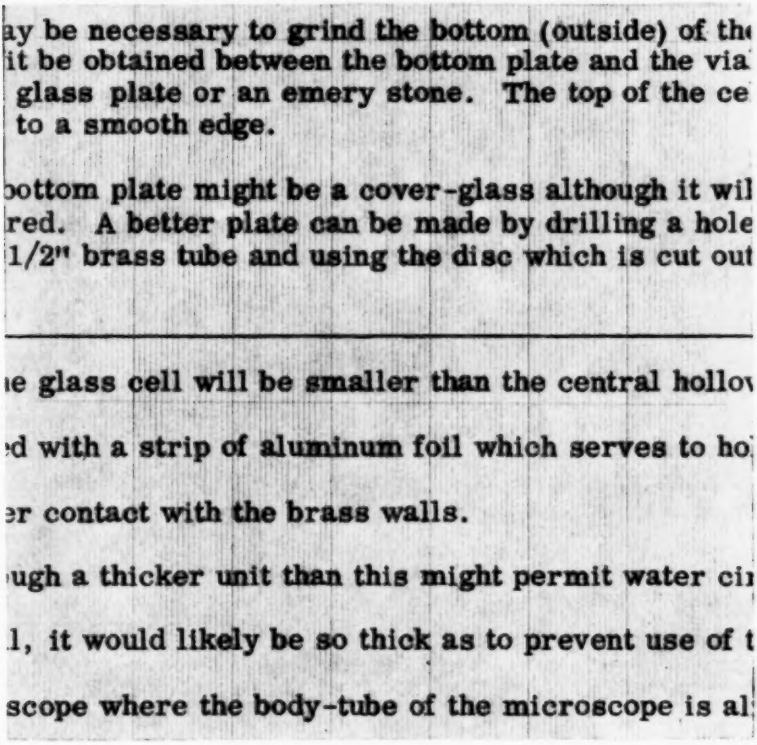
The identification of proportional spacing typewriting depends upon exactly the same factors which identify a conventional typewriter—type size, design, and a unique combination of defective and nondefective type faces. It is the in-

[7] For discussion of the design and use of these proportional spacing test plates, see the author's article, "A Test Plate for Proportional Spacing Typewriter Examination", Journal of Criminal Law, Criminology, and Police Science, Vol. 47, No. 2 (July-August 1956), pp. 257–9.

[8] IBM uses a platen 1.75 inch in diameter so that a twenty-nine teeth ratchet gives 5.28 lines per inch and a thirty teeth ratchet, six lines per inch.

[9] IBM reports that the four most popular fonts are Modern (1/32), Documentary (1/32), Mid-Century (1/36), and Arcadia (1/32).

dividuality of machines with the same font of type with which we are now concerned, the defects upon which these identifications rest. The defects include broken and damaged type faces, and malalignment—letters out of position, vertically or horizontally, or leaning away from perpendicular—and letters printing an uneven impression, off-their-feet. Rebound-


ay be necessary to grind the bottom (outside) of th
it be obtained between the bottom plate and the via
glass plate or an emery stone. The top of the ce
to a smooth edge.

ottom plate might be a cover-glass although it wil
red. A better plate can be made by drilling a hole
1/2" brass tube and using the disc which is cut out

ie glass cell will be smaller than the central hollo

d with a strip of aluminum foil which serves to ho

er contact with the brass walls.

ugh a thicker unit than this might permit water ci

1, it would likely be so thick as to prevent use of t

scope where the body-tube of the microscope is al

Fig. 16—A page of Bold Face #2 typewriting photographed under a ruled test plate for 1/36 inch escapement.

ing characters, though rare, may play a part in the identification, and (as is true of all electric typewriting machine identifications) since letters which constantly print too heavy or too light are the result of the mechanical adjustment, they serve to further individualize the typewriter. When a ma-

chine develops a defect of skipping or failing to space when a letter is struck, the defect may be revealed by a single unit extra space or two letters overlapping by one unit rather than a full letter skip or complete stacking of two characters as occurs on the conventional typewriter. Because of mechanical construction though skipping of one 3-unit letter should be found in all 3-unit characters. There are other less common typewriting defects encountered in proportional spacing typewriters as well as standard machines such as an escapement which is slightly larger or less than the design value or line spacing which is a fraction of an inch too great or too small.

Two factors, however, complicate the identification of proportional spacing typewriting. In the first place, most of the fonts are shaded, and the shaded type printing an uneven impression is not as readily recognized as a defective fine line character. This defect is common to all typewriters. The availability of nondefective reference specimens, study of impressions of what should be equal width serifs, and uneven impressions revealed under the binocular microscope help to overcome these difficulties. In the second instance alignment tolerances are closer in proportional spacing than in standard typewriting, and the irregular width of different letters tend to hide slight horizontal malalignments. However, with the use of test plates this condition can be recognized more readily.

Today with most new typewriters it is rather unusual to find broken type faces (Figure 17). It has been this writer's experience, however, that with proportional spacing fonts, particularly those with serifs, Modern and Documentary types for example, almost every machine has at least one broken type face, and with machines only a few years old, there may be several damaged faces. Many Executive model typewriters are equipped with carbon paper ribbons, and this results in even very slight chips or nicks in the type face showing up clearly in the typewriting whereas with a cloth ribbon they might be obscured.

There is one unique feature on the Executive Model, a device called an expander. When engaged, it adds one unit of spacing to each letter (Figure 18). This has no particular

effect upon the identification problem except that the examiner should understand that single spacings after the letters can be added automatically. A single unit spacing otherwise could only result from skipping in the escapement or be ac-

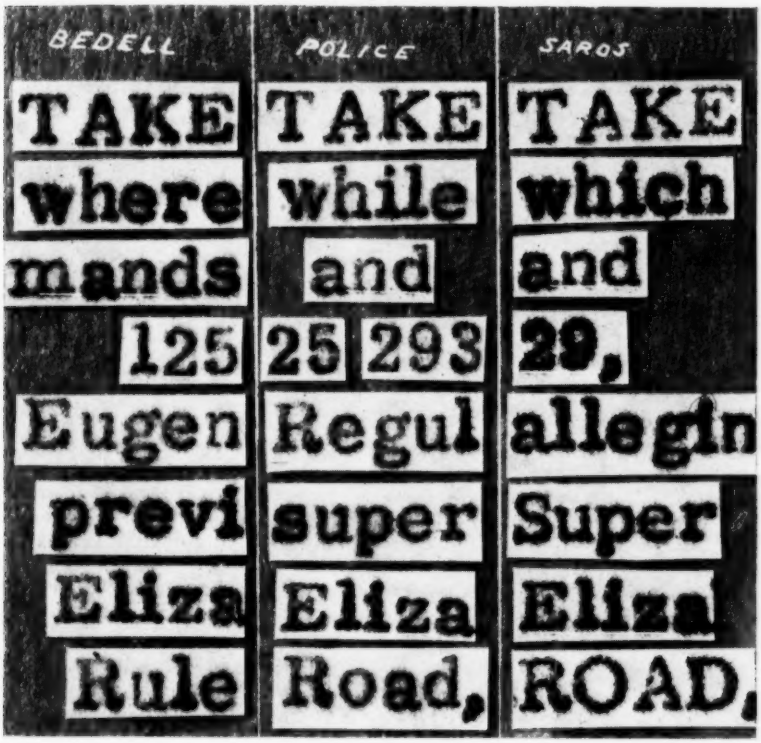


Fig. 17—Comparison of Proportional Spacing Typewriting. Three documents which should have been prepared at three different sources were found to be typewritten on the same IBM proportional spacing machine. Note especially the broken serif of the "A," "K," "w," and "p."

complished by the use of two units space bar followed by a one unit back space.[10] This latter cause calls attention to

[10] Proportional spacing typewriters have a split space bar, one-half provides for a two-unit space, the other a three-unit space. The backspacing is accomplished one unit at a time.

another feature of the machine, the divide space bar with two and three unit spacing.

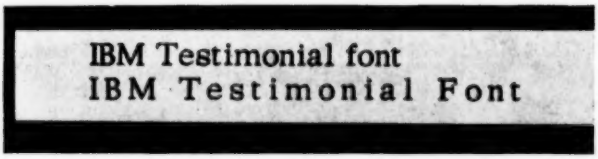


Fig. 18—Typewriting on the same machine in which the first line is written with normal spacing and the second line with expanded spacing.

Defects resulting from improper operation of the escapement mechanism in which only one unit skipping or underspacing occurs can be accurately detected by careful analysis. When two letters are crowded together or overlap by one unit, or are spread by a one unit gap, the condition may be due to defective escapement or a typist's error in operating the machine. Remember, unless a selector bail activates a wider spacing, the carriage always moves forward two units each time a key is depressed, but backspacing, on the other hand, is made one unit at a time. With typing errors requiring backspacing to insert an omitted letter it is entirely possible to have an error of one unit. On the other hand, if the defect repeats several times, especially after writing the same unit spaced letters, it undoubtedly is due to a machine defect.

Other defects which occur with proportional spacing typewriters can generally be recognized in the same way as they are in standard typewriters. It should be noted that IBM has apparently taken special precautions to eliminate rebound in their machines, for this is an extremely unusual defect. It is also true that for the most part we are dealing with newer typewriters in identification of these machines, many of them less than five years old. With standard typewriters the most difficult problems are encountered with attempts to identify new machines, and it is just as reasonable to expect with proportional spacing problems machines with less than five years use will have far fewer defects than they will ten or fifteen years from now. There will come a time, naturally,

when a number of proportional spacing machines of over ten years age will be in use just as today we find many aging standard typewriters.

Conclusions

Problems involving proportional spacing typewriters are not insurmountable. They do represent new challenges, and in some ways the problems are complicated, but if undertaken with a scientific attitude of mind and a thorough understanding of how these machines write, identification of the work of a particular typewriter follows a similar pattern to that which has been used for years in standard typewriting problems.

Acknowledgments: In the preparation of a research paper of this nature one must turn to many sources for information and assistance. Key personnel of the IBM Corporation have been most helpful, and especially J. C. Phillips, Vice-Chairman of the Board of Directors, H. W. Reis, Jr., General Manager Electric Typewriter Division, and R. C. McIntyre and J. S. Grimsley, Electric Typewriter Sales Engineering.

Various fellow workers have been kind enough to loan specimens for this study or to send photographs of file material. These include David A. Black (Los Angeles), Donald Doud (Milwaukee), Linton Godown (Memphis), George J. Lacy (Houston), John J. Harris (Los Angeles), Harry M. Ashton (Cincinnati), Mrs. Mary Beacom (Georgia State Laboratory), James V. P. Conway (Postal Inspectors Service, San Francisco), and Philip Schmitz (Veterans Administration). It was through the use of various specimens from these individuals that a more complete documentation was possible.

David A. Black of Los Angeles furnished the writer with notes on certain type face changes of the Modern font. Linton Godown of Memphis, Tennessee, has been a consistent correspondent during the course of this study, supplying extremely useful information, pointing out significant modifications in certain fonts of type, and raising stimulating questions.

Regardless of all of the suggestions and assistance offered by the above individuals, this writer must assume personal responsibility for all statements contained in this paper and for the decisions as to what to include and what to exclude, both in the discussion of the various fonts and in the general scope of the study.

Examiner of Questioned Documents
15 Park Row
New York 38, N. Y.

Factors Affecting the Deterioration of Dried Bloodstains*

*Roger W. Marsters, Ph.D.,** and Frederick C. Schlein, B.S.,*
Cleveland, Ohio

When the criminal laboratory investigator is confronted with the problem of grouping a specimen of dried blood, he must work with a biological material which may have been exposed to a wide variety of adverse conditions and be contaminated by various substances which may interfere with the subsequent reactions. Compared to fresh blood with intact erythrocytes, the grouping of a bloodstain by the absorption method is difficult. Inferences from a negative reaction should be made with caution, since such an observation may indicate either that deterioration or masking of the reaction has occurred, or perhaps that the particular reactant was never present in the blood.

The experiments presented represent a study under controlled conditions of the effects of short term exposure of fresh blood to a variety of physical conditions and contaminations. Data also are presented on the rates of deterioration of both the cell agglutinogens and serum agglutinins in a series of blood specimens allowed to remain at room temperature without preservatives.

Further, it is intended to explore the application of tube technics to bloodstain identification work. While in clinical blood grouping laboratories the use of test tubes has largely

---

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 1, 1957, Chicago, Illinois.

** Department of Pathology, Western Reserve University School of Medicine and City Hospital, Cleveland, Ohio.

superseded the use of glass slides, the use of slides is apparently still common in bloodstain identification work (1, 2, 3). Test tube procedures provide the advantages of greater sensitivity and flexibility as compared with conventional slide methods.

Methods

The determination of the OAB group of a dried bloodstain involves the testing of the stain both for cell agglutinogens and serum agglutinins. Since the erythrocytes have been disrupted in the process of drying, the cell agglutinogens are indirectly demonstrated by the ability of the stain to neutralize or absorb A or B antibodies from carefully standardized antiserums. By later addition of known A and B cells the effect of absorption by the stain can be observed.

The presence of serum agglutinins can be examined for directly by the addition of known A and B red cells under appropriate conditions. This direct test is similar to the performance of serum typing or "reversals" in typing fresh blood.

The bloodstain donors employed in this study were selected on the basis of careful cell and serum typing and included three type O, five type A, five type B, and two type AB individuals. Of the five type A donors, four were type A_1 while one (M. J.) was an A_2. The individual donors were introduced into the series so that as far as possible their OAB types represented a random order.

All donors had a titration of the appropriate A and/or B antibodies determined at some time during the course of the investigation using the same reference cells as were employed for the absorption and direct agglutinin tests. These reference cell donors were F. S. (type A) and R. M. (type B) and blood specimens from both individuals were taken fresh daily during the early part of this work and each week thereafter. There was no apparent change in reactivity of their erythrocytes throughout the study. In those experiments using these two donors for stains other known A_1 and B erythrocytes were substituted.

In addition, the erythrocytes of all donors employed in this study were titrated against the same anti-A or anti-B serum.

The resulting titers were all within ± one dilution tube and therefore the content of A or B substance in these blood specimens was apparently comparable.

The experiments presented are grouped under two headings: 1) Conditions and Contaminants Studies, where bloodstains were subjected to a variety of physical conditions and contaminants for a period of 18 hours and then grouped by the absorption technic using well slides, and 2) Room Temperature Studies, where the effect of wet storage of blood at room temperature was evaluated daily for several weeks in terms of cell agglutinogen and serum agglutinin content by use of the tube technic.

1. *Conditions and Contaminants Studies.* Before each donor was bled for these studies, the test tubes were labeled and preparations made so that no time was lost in treating the specimens as indicated. At the time each donor was bled a total of approximately 12 mls. of blood was taken. Approximately 3 mls. of this blood was mixed with a small amount of powdered heparin and then immediately dispensed dropwise directly into the bottom of each of a series of forty-four 12 x 75 mm. test tubes using the syringe support jig shown in Figure 1. The tubes were set up in pairs and each pair was treated in a different way as follows:

1) –5° C.—dry (deep freeze cabinet)
2) 22° C.—dry (room air)
3) 37° C.—dry (incubator)
4) 60° C.—dry (oven)
5) –5° C.—wet (deep freeze cabinet)
6) 22° C.—wet (room air)
7) 37° C.—wet (incubator)
8) 60° C.—wet (oven)
9) Oil soap—"Murphy's"
10) Detergent—"Super Soilax"
11) Detergent—"Tide"
12) Fingerprint powder, commercial type, Faurot Company
13) Fingerprint powder, lead carbonate
14) Fingerprint powder, commercial type, Farco Company

15) Fingerprint powder, mixture compounded and used by the Cleveland Police Department
16) Fingerprint powder, commercial type, Farco Company
17) Fingerprint powder, mixture compounded and used by the Cleveland Police Department
18) Fingerprint powder, mixture compounded and used by the Cleveland Police Department
19) Urine—all from type B secretor donor

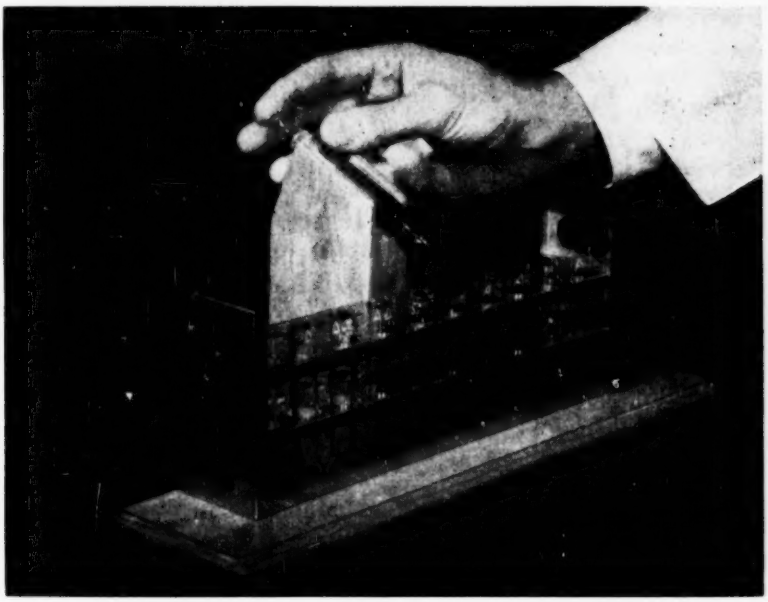


Fig. 1—Device for making constant volume blood stains.

20) Human perspiration contamination: First ten stains with type A non-secretor donor and remaining five type B secretor donor
21) Bacterial contamination—*Staphylococcus aureus*
22) Exposed to ultraviolet radiation

The first eight pairs of tubes were exposed to different temperatures and rates of drying. The first four pairs were

left open while the second four pairs were stoppered with corks covered with moistened cotton.

The effects of detergent contamination were studied by either adding the detergent solutions in 0.1 ml. quantities directly to the stains, or by preparing the tubes ahead of time with 0.1 ml. of the detergents dried in the tubes and then adding the blood to the tubes. The detergents and the oil soap were made up in the strengths recommended by the manufacturer and were approximately two to three per cent solutions.

The quantity of the various fingerprint powders dusted over the stains was just sufficient to cover the natural blood color. The powders were added after the stains had dried.

All urine was from donor R. M. who was type B and a known saliva secretor. The perspiration employed was either from a type A non-secretor donor (F. S.) or from a type B secretor donor (R. M.). The stains were contaminated by adding 0.1 ml. perspiration or urine to the blood in the test tubes.

Bacterial contamination was produced by depositing a small drop of an active *Staphylococcus aureus* culture in the drop of blood with an applicator stick as soon as the stains were made. This particular organism was selected since it is a common contaminant of human living quarters.

The exposure to ultraviolet radiation was made with the open mouth of the test tube pressed against a G. E. Sterilamp. In this position the ultraviolet radiation fell directly on the bloodstain at a distance of approximately 75 mm.

The test tubes were prepared with the conditions and contaminants indicated above and left for a period of approximately 18 hours until the following morning. At this time the tubes were reassembled and 0.1 ml. of appropriately diluted anti-A and anti-B antiserum was added to each pair of tubes. The tubes were shaken thoroughly to disperse the blood stain through the antiserum, corked, and placed in the refrigerator at 5° C. for 24 hours. At this time the tubes were removed and shaken thoroughly. One capillary drop of each mixture was placed in a depression of a Boerner well slide with one capillary drop of a one per cent suspension of the appropriate type A_1 or type B erythrocytes. The slides were

placed upon a horizontal platform rotating machine for 10 minutes at 80 rotations per minute and then removed and read over a white background. No direct tests for agglutinins were carried out with the conditions and contaminants studies, although three entire sets of stains were also set up and read in test tubes after two hours' incubation at room temperature.

For the study of the effects of various conditions and contaminants on the deterioration of the blood agglutinogens, it was essential that the same amount of blood be present in each of the various absorption tests. It was first planned to make the simulated stains on glass microscope slides but preliminary experiments with drops of blood on glass surfaces showed that after drying the stain tended to form flakes which were difficult to handle and transfer quantitatively. Consequently it was decided to make the "stains" directly in the bottoms of the absorption test tubes and the syringe support device illustrated in the photograph was constructed to standardize this procedure. With this device a 5 ml. syringe fitted with a number 22 gauge needle was maintained at constant angle and position in relation to the base. The tip of the needle was carefully ground off square and was approximately three inches (78 mm.) from the bottom of the test tube.

By means of gentle pressure on the plunger of the syringe replicate drops of blood could be produced with satisfactory accuracy. In two series of twelve drops each made consecutively, the average weights per drop were 26.2 mg. (donor R. M.) and 25.3 mg. (donor F. S.).

As a result of this discrepancy the hemoglobin concentration of these two individuals was determined and it was shown that the donor with the heavier drop had 1.2 Gm. per cent higher hemoglobin concentration. The individual drops showed good uniformity because almost 90 per cent of the weights of the individual drops in the two series were within $\pm$ 1.5 mg. of the average. In addition, several ml. of blood from the donors were delivered and the number of drops counted. The average volume of the individual drops was 0.033 ml. On a flat glass surface the drops of blood formed by employing this syringe support device measured 11–12 mm. in diameter.

2. *Room Temperature Studies.* For the study of the rates of deterioration of both the cell agglutinogens and serum agglutinins in blood left at room temperature, blood from each donor was delivered into 12 x 100 mm. test tubes and allowed to clot. These specimens were placed in a deep freeze cabinet at –5° C. and alternately thawed and refrozen several times until the following day and then allowed to remain at room temperature.

The presence of the agglutinogens and agglutinins was determined daily six days per week until the results were consistently negative or until the experiments had to be terminated for lack of sufficient specimen to continue.

In these experiments the test tube technic was employed with 10 x 75 mm. test tubes and incubation for two hours at room temperature. In trials where the tubes were left longer than two hours for periods up to 24 hours there was no significant enhancement in the strength of reactions. In all cases separate absorptions with anti-A and anti-B serums were employed. These antiserums were shown not to contain dissolved A or B antigen substances. No absorption studies using O serum were attempted because the natural A and B antibodies of such serums are apparently not the same as the corresponding antibody in type A or type B blood (4).

All tubes were read with a magnifying mirror under a strong light. By use of this technic the endpoint of most serum titrations is less than one dilution tube below the usual "trace" microscopic endpoint. Centrifugation at low speed for one minute did not enhance the reactions as compared to allowing the tubes to remain quietly in the racks for two hours' time.

Each day direct agglutinin tests were performed employing type A_1, B, and O cells. Absorption tests were also performed using these same three test cells, each in the presence of anti-A and anti-B serums. Thus a total of nine separate tubes were set up daily for each room temperature blood. The use of type O cells was discontinued after the first few weeks because of consistently negative results. The use of A cells with the anti-B absorptions, and B cells with anti-A, provided a control on the direct agglutinin tests and the data so obtained are included in the results presented.

In these test tube reactions one capillary drop (volume 0.033 ml.) of one per cent cells was employed with 0.1 ml. of the appropriate antiserum. Thus the erythrocyte strength resulted in a final concentration of 0.25 per cent which furnishes at least four times the sensitivity as when equal quantities of 2 per cent cell suspension and serum are mixed. Lund (5) has pointed out that increased sensitivity can be attained if a relative excess of antibody is present in relation to the erythrocyte antigen available.

Results

1. *Conditions and Contaminants Studies.* The results of treatment with the various conditions and contaminations showed a high degree of stability of the blood agglutinogens within the 18 hour period covered by these observations. The results observed are summarized in Table I with the significant reactions outlined. The effect of heating to 37° C. or 60° C. and maintaining the blood in its liquid state was associated with no significant loss of neutralizing capacity in the absorption tests.

The oil soap and one of the detergents (Tide) caused rapid hemolysis of the test cells. With the other detergent (Super Soilax) we were surprised to observe no hemolysis although the presence of this particular detergent interfered with the expected reactions.

The effects of the various fingerprint powders were essentially negative although the powders themselves confused the readings because of their presence.

Contamination by bacteria caused no demonstrable effects.

The effects of the 18 hour exposure to the direct rays of a G. E. germicidal lamp at a distance of only 75 mm. were not discernible in the absorption tests. These lamps emit approximately 90–95 per cent of their radiation at a wave-length of 254 millimicrons and will cause severe skin burns and retinitis even after less than one hour's exposure to the radiation. A significant effect was probably not to be expected because of the low penetrating power of these rays.

However, the effects on the absorption tests of contamination from various body secretions were highly significant if the donor of the secretion was a saliva secretor of blood group

substance. The effect of adding urine or perspiration from a type A non-secretor donor was not detectable on any one of ten bloods (four A's, five B's and one AB). On the other hand, both urine and perspiration from a known type B secretor caused three type O donors to react as though these bloods were type B. The effect of the urine was more pro-

TABLE I

CONDITIONS AND CONTAMINANTS OBSERVATIONS

Stain Donors OAB Blood Type

	B		A		AB		B		A		B		A		B		A2		B		O		A		O		O		AB	
CONDITIONS	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B	-A	-B
-5° C Dry	2+	0	0	2-	0	0	4+	0	0	2+	4-	0	0	2-	2+	0	2+	3+	3-	0	2-	2-	0	1+	3-	1+	1+	tr	0	0
22° C Dry	2+	0	0	2+	0	0	4-	0	0	2+	4-	0	0	2+	2+	0	2+	3-	3-	0	3-	3-	0	2+	3-	2+	3-	2+	0	0
37° C Dry	2+	0	0	2+	0	0	4-	0	0	2+	3-	0	0	2+	2+	0	2+	3-	3-	0	3-	3-	0	2+	3-	2+	3-	2+	0	0
60° C Dry	1+	0	0	2-	0	0	2+	0	0	2-	2+	0	0	2-	2-	0	2-	2+	2+	0	2+	2+	0	2+	2+	2+	2+	2-	0	0
-5° C Wet	2+	0	0	2+	0	0	3+	0	0	2+	2-	0	0	2+	2+	0	2+	3-	2+	0	1+	2-	0	2+	1+	1+	1+	tr	0	0
22° C Wet	2+	0	0	2+	0	0	tr	0	0	2+	2-	0	0	2-	2-	0	2-	2-	2-	0	2-	2-	0	2-	2-	tr	2+	2-	0	0
37° C Wet	2+	0	0	2+	0	0	tr	0	0	2+	2+	0	0	2+	2+	0	1+	2+	2+	0	3-	3-	0	2+	2+	2+	3-	2+	0	0
60° C Wet	1+	0	0	1+	0	0	2+	0	0	2-	tr	0	0	2-	2-	0	tr	2+	2-	0	1-	1-	0	1+	1+	2-	1+	1+	0	0
Oil Soap	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Detergent SS	0	0	0	tr	0	0	2+	0	0	2-	2+	0	0	1+	1+	0	1-	1-	1+	0	2+	2+	0	1-	2-	2-	2+	1+	0	0
Detergent T	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Fingerprint Powder #1	2+	0	0	1+	0	0	2+	0	0	2+	2+	0	0	2+	2+	0	1+	2+	2+	0	2+	2+	0	2-	2+	2-	3-	1+	0	0
" #2	2+	0	0	2-	0	0	4-	0	0	2+	4-	0	0	2+	2+	0	2+	3-	2+	0	3-	3-	0	2+	3-	2+	3-	2+	0	0
" #3	2+	0	0	2-	0	0	4-	0	0	2+	3+	0	0	2+	2+	0	2+	3-	2+	0	3-	3-	0	2+	3-	2+	3-	2+	0	0
" #4	2+	0	0	2-	0	0	4-	0	0	2+	2+	0	0	2+	2+	0	2-	2+	2+	0	3-	3+	0	2+	2+	2+	3-	2+	0	0
" #5	2+	0	0	2-	0	0	3+	0	0	2+	3+	0	0	2+	2+	0	2+	3-	3-	0	3-	3-	0	2+	3-	2-	3+	2+	0	0
" #6	2+	0	0	2-	0	0	3+	0	0	2+	3-	0	0	2+	2+	0	2+	3-	3-	0	3-	3-	0	2+	3-	2-	3+	2+	0	0
" #7	2-	0	0	2+	0	0	2+	0	0	2+	2+	0	0	2+	2+	0	0	2+	2+	0	3-	3-	0	2+	2-	2+	3-	2+	0	0
Urine	1-	0	0	2-	0	0	2-	0	0	1+	2-	0	0	0	2-	0	0	0	2+	0	2+	0	0	0	2-	0	2+	0	0	0
Sweat	tr	0	0	1+	0	0	2-	0	0	2-	1+	0	0	2+	1+	0	2+	2-	2+	0	2+	1+	0	0	2+	1+	3-	tr	0	0
Staph. Aureus	2+	0	0	2+	0	0	2+	0	0	1+	2-	0	0	2-	2+	0	1+	2+	1+	0	2-	2-	0	1+	2-	1+	tr	1-	0	0
Ultraviolet	2+	0	0	2+	0	0	2-	0	0	2+	2+	0	0	2+	2-	0	1-	2+	2+	0	2+	2+	0	2+	2+	2+	3-	2+	0	0

4 = hemolyzed

tr. = trace

nounced than the effect of perspiration. With type A donors the effect of B secretor urine was to give an absorption effect as would be obtained with an AB stain. With both known AB stains there was no observable effect of either contamination.

With the exception of the detergent and body secretion contaminations, the remainder of the conditions and contaminants observations indicate that, while the expected reaction was usually present, that great degrees of variability in the strength of reaction were observed. Positive reactions ranging from less than one-plus to four-plus were observed, while the positive controls were uniformly two-plus in strength. It is reasonable to believe that this range of variable reactivity might be encountered among the bloodstains found in a non-uniformly contaminated room, as for example the scene of a homicide, depending on the number of the bloodstains tested.

Bloodstains from a single victim could easily be subjected to the entire variety of situations presented in these experiments. Bloodstains will dry at different rates, and contamination from soaps, detergents, and body fluids from secretor donors is always possible.

The absorption tests on the type A_2 blood under various conditions and contaminants demonstrated even greater departures from the expected reactions. Frequently there was some clumping with the A_1 test cells so that this blood usually reacted as a type O. In a few cases however, this A_2 blood completely absorbed the anti-A serum and behaved as a type A, and with contamination from B secretor urine it reacted as a type AB (see Table I).

2. *Room Temperature Studies.* The results of the study on the deterioration of agglutinogens and agglutinins in blood left at room temperature are shown in Table II. In all cases the cell agglutinogens were still present at the time the observations were terminated. The average period of observation for the persistence of cell agglutinogens was over 26 days.

In these studies on bloods left at room temperature all absorptions were checked with reverse controls where A_1 cells were set up with anti-B absorptions, and B cells with anti-A absorptions. If clumping occurred it served as a check on the

direct test for agglutinins. Clumping of this nature occurred regularly and the data so obtained are presented in Table II, in the "Reverse Control" columns. It can be seen that these results are close to the observations made directly but repre-

TABLE II

AGGLUTINOGENS AND AGGLUTININS IN BLOODS KEPT AT ROOM TEMPERATURE

Donor	Int.	Agglutinogens Still Present	Persistence of Agglutinins				A/B Titer
			Direct		Reverse Control		
			Anti-A	Anti-B	Anti-A	Anti-B	
R.M.	B	32 days	11	—	9	—	1:8
F.S.	A	30 days	—	5	—	6	1:2
R.S.	AB	25 days	—	—	—	—	—
H.G.	B	22 days	16	—	14	—	1:16
J.S.	A	21 days	—	13	—	13	1:16
W.B.	B	21 days	21+	—	21+	—	1:32
G.C.	A	32 days	—	10	—	10	1:16
B.D.	B	31 days	22	—	17	—	1:32
M.J.	A	28 days	—	13	—	13	1:16
H.L.	B	24 days	24+	—	24	—	1:32
B.B.	O	(24 days)	19	18	14	15	1:128/1:64
P.R.	A	25 days	—	17	—	17	1:16
K.L.	O	(26 days)	18	21	19	19	1:16/1:16
A.N.	O	(26 days)	24	17	19	14	1:32/1:8
J.B.	AB	26 days	—	—	—	—	—
Average Days Persistence			19.4	14.2	18.3	13.4	

sent apparently shorter time periods due to the dilution with the antiserum used for absorption.

The effect of the presence of the agglutinins may also be observed in the absorption tests as an enhancement of the clumping of the A_1 test cells with anti-A serum as for example, in the case of type B bloodstain. This is termed the "additive effect" and it can be seen with either A or B stains but it is particularly impressive when it is observed in absorption tests with fresh type O blood when both A and B test cells clump stronger than the controls. In the experiments presented here this "additive effect" was not observed with any uniformity.

In the blood specimens left at room temperature, the anti-A agglutinins persisted for about one-third longer than the anti-B agglutinins in confirmation of the impression held by

previous workers (2). Titrations of the A and/or B antibodies in the fresh serums against the same reference cells used for the absorption tests indicated some correlation between height of titer and longer period of persistence of the corresponding antibody. The titration endpoints for each serum are presented in the last column of Table II.

Discussion

The data from the Conditions and Contaminants Studies emphasize the variability which can be expected to occur when the same blood is subjected to a series of diverse situations even though processed later under the same conditions.

The effect of contamination from body secretions of a secretor donor was exactly the same as if his blood were added to the stain. Secretors for A and B substances occur frequently (approximately 85 per cent of combined incidences of types A, B, and AB) and such contamination by secretor fluids can produce serious error in absorption tests.

The detergent "Super Soilax" was not observed to cause hemolysis of the test cells, but in spite of this the presence of this particular detergent interfered with the expected reactions. The interference from such contaminants in bloodstain grouping will probably increase as the use of detergents becomes more widespread. Most detergents in common use, however, are of the cationic or anionic type and are actively hemolytic.

Attention has been previously called to the non-reliability of tests performed on bloodstains contaminated with surface active agents such as saponins and detergents by Kirk, Brown and Conners (6). These authors state that "This phenomenon was encountered in grouping blood by the inhibition method for bloodstains soaked from a rug. It was not uniform, in that some spots did not produce lysis of the cells, but there was no clumping when clumping might have been expected, thus leading to a possible incorrect group."

Apparently not all surface-active compounds have such lytic effects. It has been shown by Glassman (7) that certain synthetic nonionic surface-active compounds are non-hemolytic and possessed of a low animal toxicity although capable of depressing the surface tension of water solutions. The

possible contamination of a bloodstain by a non-hemolytic detergent agent poses a real problem to the crime laboratory technician. Such a detergent as "Super Soilax" can interfere with the reactions and yet fail to give notice of its presence by the usual lytic effect on the test cells.

The experiments presented under the heading Room Temperature Studies were designed partially to simulate the conditions found in the cadaver left at room temperature.

The purpose of the initial repeated freezing-thawing was to free the agglutinogens from the cells at the beginning of the period of observation so that the absorption tests would be more comparable with such tests as applied later when the cells would have undergone dissolution.

No attempt was made to maintain sterility of these specimens kept at room temperature. The blood specimens showed retention of fragments of the clot for as long as two or three weeks. The color of the specimens demonstrated the familiar changes from red to raspberry to black with the development of the characteristic putrid odor of decayed blood. In spite of this, the cell agglutinogens persisted for as long as the observations were made, which in some cases was as long as one month.

The two type AB donors gave consistently negative results throughout the absorption studies and no activity was demonstrable in these two serums throughout the entire period of observation in the bloods kept at room temperature. Since type AB bloods do not possess either A or B serum antibodies, the inclusion of these two bloods served as a negative control in the room temperature deterioration studies for the direct agglutinins. The negative results on the absorption tests reflects the neutralization of both A and B serums used for the absorptions. Thus, type AB bloods will produce negative results on all such tests which points up the difficulty in correctly identifying bloodstains of this particular type. Almost as perplexing are the absorption tests on type O bloodstains, where the lack of absorption raises the question of possible deterioration, although the data presented here on the persistence of A and B agglutinogens tend to furnish added significance to such negative absorption results. Therefore, with

type O bloodstains, the "additive effect", when it is observed, gives confirmation and significance to an otherwise negative and inconclusive absorption result.

The use of test tubes rather than slides has the great advantage that the reaction mixtures do not dry out and, if necessary, additional incubation or reagents may be added to clarify a particular reaction. In addition, the readings are more clearcut since the erythrocytes will settle to the bottom of the tube while the debris tends to float away as the tubes are being read. It was found that neither centrifugation nor standing longer than two hours enhanced the agglutination reactions. Standing in round-bottomed test tubes caused the cells to be thrown into intimate contact with one another and the agglutination process was thereby accelerated. Erythrocytes which were not sensitized by specific antibody would later disperse discretely as shown by the type O controls.

This contact of sensitized erythrocytes is essential to the agglutination reaction, since the obvious effect of coating with specific antibody is to cause the erythrocytes to become sticky and not to endow them with any innate mobility. Perhaps the least sensitive method of all is the use of flat slides without agitation. Thus Merkeley (8), who employed this method for the study of bloodstains, observed in some cases that reactions do not begin before sixteen hours incubation.

Conclusions

An evaluation of some of the factors affecting the deterioration of blood group agglutinogens has been presented. The range of reactivity observed in absorption tests on bloodstains all derived from the same donor serves to emphasize the importance of testing several stains, if available, before deciding on the blood group. The possibility of contamination with body secretions and/or detergents must be considered, since such contamination can cause gross error in the interpretation even under ideal conditions.

It is obvious from these results that quantitative differences in the agglutinin or agglutinogen content of blood derived from different smears subjected to unknown degrees of contamination would be of no significance in establishing that the samples were derived from different individuals.

Results have also been presented of a study on the stability of cell agglutinogens and serum agglutinins in unpreserved blood specimens kept at room temperature.

Acknowledgments: We wish to acknowledge the encouragement and counsel of Dr. Alan R. Moritz throughout the duration of this investigation. We also wish to thank Captain David Kerr of the Cleveland Police Department for making available samples of the various fingerprint powders.

REFERENCES

1. Wiener, A. S., and Gordon, E. B.: Examination of Blood Stains in Forensic Medicine. J. Forensic Sc. 1:89–102 (July) 1956.
2. Harley, D.: Medico-Legal Blood Group Determination. New York, Grune & Stratton, 1945, pp. 48–54.
3. Schiff, F., and Boyd, W. C.: Blood Grouping Technic. New York, Interscience Publishers, 1942, pp. 166–175.
4. Grove-Rasmussen, M., Soutter, L., and Levine, P.: A New Blood Sub-Group (A_0) Identifiable with Group O Serums. Am. J. Clin. Path. 22:1157–1163, 1952.
5. Lund, H.: Relation of the Concentration of Red Blood Cells to the Sensitivity of the Isoagglutination Reaction. Arch. Path. 31:458–466, 1941.
6. Kirk, P. L., Brown, C., and Conners, A. B.: Some Problems in Blood Testing and Grouping. J. of Crim. Law, Crim. & Pol. Sci. 45:80–84, 1954.
7. Glassman, H. N.: Hemolytic Activity of Some Nonionic Surface-Active Agents. Science, 111:688–689, 1950.
8. Merkeley, D. K.: Isoagglutinins in Dried Blood Stains. Am. J. Clin. Path. 23:190–192, 1953.

Department of Pathology
Western Reserve University School of Medicine and City Hospital
Cleveland, Ohio

Microscopic Identification of Man-Made Fibers from the Criminalistics Point of View*

*Anthony Longhetti, B.A., and George W. Roche,** M.S.,*
St. Paul, Minnesota

By 1910, centuries of trial and error had narrowed the field of textile fibers to the point where cotton, wool, silk, and linen dominated the industry. Efforts to find substitutes for silk resulted in the production of the first man-made fiber, viscose rayon. Within the next 25 years acetate and cuprammonium rayon were successfully introduced as textile fibers, and by 1935 regenerated cellulose represented about 5% of the per capita quantities utilized by consumers in the United States (1). It was shortly thereafter that the search for new fibers, not only as substitutes but also on their own merit, led to the production of the first synthetic fiber, nylon. This was followed during the next 20 years by the production of such synthetic polymers as polyethylene, polyacrylonitrile, polyesters, and others to form an ever-growing array of fibers. The production of man-made fibers in the United States for 1950 represented 1,375,000,000 lbs. or 21.8% of the total including wool, cotton, and silk (2, 24). It has been estimated that by 1970 these figures will have risen

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 1, 1957, Chicago, Illinois.

** Crime Detection Laboratory, Bureau of Criminal Apprehension, State of Minnesota: A. Longhetti, Microanalyst and G. W. Roche, Laboratory Director.

to 3,500,000,000 lbs. (3), which is about 50% of the total fiber production expected at that time.

If the basic premise that textile fibers are one of the most frequently occurring types of microscopic evidence is accepted, there can be little doubt regarding the importance of their accurate identification in the field of Criminalistics. It is expected that, with careful microscopic examination, the general differentiation between natural and man-made fibers 21.8% of the total including wool, cotton, and silk (2, 24). It can be made. Among the natural fibers, cotton and wool rarely present an identification problem, although this is not necessarily true of other vegetable and animal fibers. Man-made fibers, on the other hand, can seldom be conclusively identified upon microscopic examination alone. Solubility, spot tests, appearance of cross-section, reactions to identification stains, burning tests, and physical properties such as refractive index, density, and melting point have been used as the basis for several schemes of analysis applicable to man-made fibers (4–17). These schemes have, for the most part, been developed for the benefit of textile chemists working with relatively unlimited amount of sample and can not easily be adapted to the identification of a single fiber. Although there are available in the literature methods which can be made applicable to a single fiber (18–22, 25), these were usually found to be based on a limited number of undyed samples obtained directly from the manufacturer. Many of these schemes deal only with the synthetic fibers, excluding the large group of regenerated cellulosics; and, as is to be expected, none includes the newer synthetics such as Arnel, Verel, and Darlan.

CLASSIFICATION OF FIBERS

In order to better understand the scheme for the identification of man-made fibers which is to be developed here, the fibers have been subdivided as shown in Figure 1. There is also presented a brief description of the chemistry and manufacturing processes involved (23, 24, 26, 33, 35, 36).

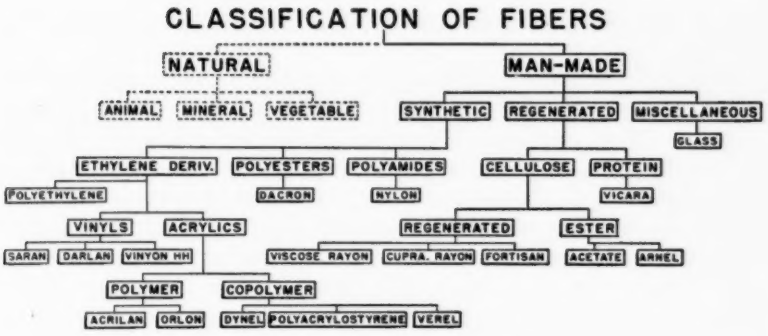


Fig. 1—Classification of Fibers

Synthetics

Polyamides: Nylon (which can be further subdivided into nylon 66 and nylon 6) is the only polyamide fiber manufactured commercially in the United States. Nylon 66 fiber is formed from a polymer,

$$-(CH_2)_4-CO-NH-(CH_2)_6-NH-CO-$$

which is synthesized from hexamethylenediamine and adipic acid. The nylon 6 fiber is derived from the polymer, ϵ-aminocaproic acid (caprolactam),

$$-NH-(CH_2)_5-CO-$$

In both instances the polyamide is melted and extruded through a spinneret, where the resulting fiber is frozen in a current of air and then stretched to increase tensile strength and elasticity. Disperse and acid dyes are normally used for nylon 66, although all other types can be used. All types of dyestuffs are used for nylon 6 since it is alleged to have a greater affinity for dye and take a deeper shade than nylon 66.

Polyesters: Dacron is the only polyester fiber manufactured commercially in this country. It is made from ethylene glycol and terephthalic acid either by direct esterification or by a catalyzed ester-interchange reaction, resulting in the formation of the "terylene" polymer,

$$-(OCH_2CH_2O-OCC_6H_4CO)_n-$$

The polyester is melted, extruded through a spinneret, and subsequently stretched. Dacron can be dyed to most desired

shades with dispersed acetate dyes and azoic dyes with carrier.

Ethylene Derivatives: Polyethylene resin is formed by the polymerization of liquid ethylene at high temperature and pressure. The resin is extruded in the molten state where the fibers are cooled in air or water, oriented by cold drawing, and stretched. Polyethylene fibers are not dyed but may be pigmented before extruding.

The *vinyls* produced as fibers in the United States are copolymers; Darlan, of vinylidene chloride and dinitrile; Saran, of vinylidene chloride and vinyl chloride; and Vinyon HH, of vinyl acetate and vinyl chloride. In the manufacture of Saran the copolymer,

$$-(CH_2CHCl-CH_2CCl_2)_n-$$

is melted and extruded to form filaments which are then oriented and mechanically stretched. Vinyon HH is formed from the acetone-soluble copolymer,

$$-(CH_2CHCl-CH_2CHOCOCH_3CH_2CHCl)_n-$$

which is spun from solution, frozen by a current of warm air, and set by heating under tension. Though both Saran and Vinyon HH can be dyed by the use of special procedures, the former is normally pigmented before extrusion while the latter is seldom dyed. Manufacturing procedures and dyeing processes for Darlan were not readily available at the time of this writing.

Acrylics: Orlon is formed from the polyacrylonitrile polymer,

$$-(CH_2CHCN-CH_2CHCN)_n-$$

obtained by the addition-type polymerization of acrylonitrile (vinyl cyanide). The polymer is dissolved in a suitable organic solvent, the solution extruded through a spinneret, and the solvent removed to form the fiber. Orlon can now be dyed with basic, acetate, acid (copper technique), naphthol, and vat dyes to most desired shades.

Acrilan is formed from acrylonitrile combined with small quantities of other related monomers. The resulting polymer is dissolved in a suitable solvent, the solution extruded through a spinneret, and the solvent removed to form the

fiber. Acrilan is dyed with basic, acetate, acid, chrome, premetallized, and vat dyes to most desired shades.

Dynel is formed from a copolymer of acrylonitrile and vinyl chloride,

$$-(CH_2CHCl-CH_2CHCN)_n-$$

The 40:60 copolymer is dissolved in acetone, spun, stretched and stabilized. Dynel is colored by most types of dyes (acetate, acid, direct, basic, and premetallized) at somewhat elevated temperatures.

Verel is described as a modified acrylic fiber formed from a copolymer of acrylonitrile together with other monomers.

Polyacrylostyrene is a copolymer of acrylonitrile and polystyrene. It is seldom dyed except by incorporating pigment with the melt before extrusion.

Regenerated Fibers

Cellulose: Viscose rayon is formed from purified cellulose which has been treated in alkaline solution with carbon disulfide to make cellulose xanthate,

$$-\left\{(C_6H_9O_4)_2\text{–OH–OC}''\begin{matrix}S\\ \diagdown SNa\end{matrix}\right\}_n-$$

After aging, the cellulose xanthate is extruded through a spinneret, hardened in an acid bath, washed, and stretched. Viscose rayon is dyed in essentially the same manner as cotton, using direct, vat, azoic, basic, mordant, pigment, and sulfur dyes.

Cuprammonium rayon is formed from raw material containing a high percentage of alpha-cellulose. The cellulosic material is dissolved in copper ammonium hydroxide (Schweitzer's Reagent), after which the resulting solution is extruded through a spinneret, drawn out in a water bath, and passed through a dilute sulfuric acid bath to destroy the cuprammonium complex and precipitate the cellulose. The fibers are dyed in much the same manner as cotton and viscose rayon.

Fortisan is formed by the saponification of highly oriented cellulose acetate. Extremely high strength and resistance to stretch is thus imparted to the fiber. Fortisan is also dyed

in the same manner and with the same range of dyes as cotton and the other regenerated cellulose fibers.

Acetate is formed from cotton linters or wood pulp which has been acetylated with acetic anhydride and partially hydrolyzed to form a compound approximating a *di*acetate. The diacetate is dissolved in acetone, extruded through a spinneret, and frozen in a current of warm air. Dyes used on acetate include vat, azoic, special acetate dyes, basic, and some acid and mordant dyes.

Arnel is formed from cellulose *tri*acetate, the hydrolysis having been allowed to proceed longer than in the case of acetate. Dyes used include selected dispersed acetate dyes, developed azo colors, and solvent dyeing.

Protein: Vicara is the only regenerated protein fiber now produced commercially in the United States. It is formed from the prolamine fraction of corn protein (zein) which has been denatured, suspended in alkaline solution, and allowed to age. The resulting solution is extruded into an acid-formaldehyde precipitating bath in which the fiber is formed. Vicara can be dyed with all wool-type dyes such as acid, chrome, mordant, vat, and indigo.

Miscellaneous

Glass: Glass fibers are formed from glass marbles which are melted in a furnace with minute holes in the base; and the resulting fiber is attenuated to the desired size (filament form) or sprayed with jets of steam or air (staple form). The ceramic fiber (Fiberfrax) is formed from aluminum silicate in somewhat the same manner as the staple form of glass fiber. Surface dyeing techniques using resin-bonded pigments and special procedures using protein film applied during manufacture for vat, direct, acid, and chrome dyes have been utilized for coloring glass fibers.

IDENTIFICATION SCHEME

A total of 18 man-made fibers which were being produced commercially in the United States by the end of 1956 were studied (Table 1).

TABLE 1. Fibers Used in Study

Acetate	Nylon
Acrilan	Orlon
Arnel	Polyacrylostyrene
Cuprammonium rayon	Polyethylene
Dacron	Saran
Darlan	Verel
Dynel	Vicara
Fortisan	Vinyon HH
Glass	Viscose rayon

Two sources of fiber samples were utilized; (1) manufacturers of the fiber, and (2) the producer or seller of the consumer goods. 21 manufacturers supplied representative samples (in most cases both dyed and undyed) of all fibers listed in Table 1. 25 retailers and wholesalers of yard goods, draperies, carpets, upholstery, and wearing apparel in the St. Paul-Minneapolis area supplied samples of 13 of the fibers listed in Table 1.

Experimental:

Microscopic Examination

A total of 595 fiber samples were examined microscopically in longitudinal section (Table 2). Examinations were made at a magnification of 440X using transmitted light. Efforts were made during the microscopic observations to find criteria which would divide the fibers into two or more primary groups and which were definitive and constant enough to ensure accurate results when only a single fiber was examined. As a result of the microscopic examinations, it was possible to divide the 18 fibers into two basic groups; striated (8 fibers) and non-striated (10 fibers) (Figures 2 and 3). The *non-striated* fibers are characterized by a round or slightly oval cross section. In longitudinal section the fiber appears *smooth* and without longitudinal striations or canals and with constant diameter along its entire length. Focussing down from the top center of the fiber brings both edges into

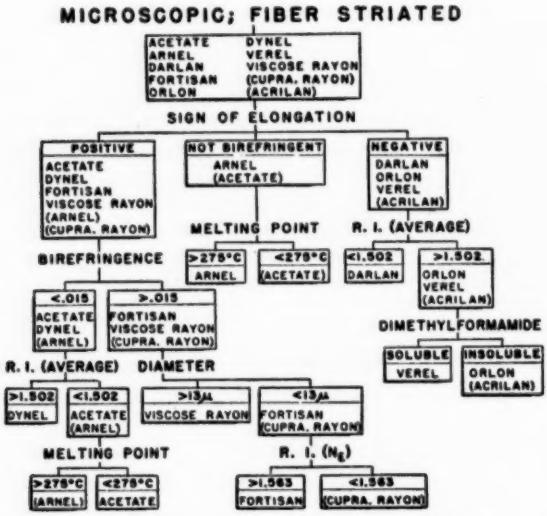


Fig. 2—Identification Scheme for Striated Fibers

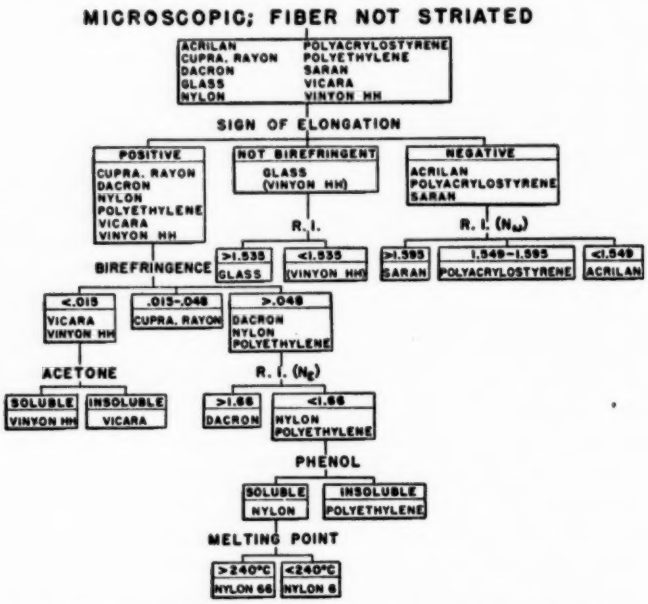


Fig. 3—Identification Scheme for Non-striated Fibers

sharp focus at the same time. Some surface "pitting" or fibrillation (series of longitudinal "cracks" resulting from stretching process) may be present along some areas, but this does not detract from the smooth appearance of the fiber. The *striated* fibers are characterized by a *non-smooth* cross section which varies from a "dumbbell" shape such as that of Orlon to a serrated appearance such as that of viscose rayon. In longitudinal section the fiber will show either a series of longitudinal striations running the entire length of the fiber or

TABLE 2. Number of Fiber Samples Mounted

Fiber	From Manufacturer	From Retailer or Wholesaler	Total
Acetate	57	36	93
Acrilan	28	20	48
Arnel	12	14	26
Cuprammonium rayon	17	20	37
Dacron	5	42	47
Darlan	3	–	3
Dynel	1	7	8
Fortisan	2	39	41
Glass	21	12	33
Nylon	16	65	81
Orlon	7	48	55
Polyacrylo-styrene	1	–	1
Polyethylene	2	–	2
Saran	2	1	3
Verel	5	–	5
Vicara	4	12	16
Vinyon HH	1	–	1
Viscose rayon	60	35	95
			595

a canal (false "lumen") which may vary in width among the fibers. The number of striations may vary from as little as 2 to as many as 10–12. Focussing down from the top center

of the fiber does *not* bring both edges into focus at the same time.

A decision as to whether a single fiber belongs to the striated or non-striated group should not be made in many cases without reference to standard examples of each type. Nylon and Vicara are good examples of the non-striated type; acetate and Orlon are good examples of the striated type. Although a fiber can normally be classified into one of the two types when examined in dry mount, it was found advantageous in those few cases where the difference was somewhat fine to mount the fiber in a liquid whose refractive index differed from that of the fiber by about 0.1. Amyl alcohol (1.409) and methylene iodide (1.737) are two liquids suitable for this purpose.

Cuprammonium rayon and Acrilan were found to be variable enough to be included in both categories, although it is expected that both would fall into the non-striated group with but relatively few exceptions. However, four samples of heavily delustered cuprammonium rayon received from the manufacturer were found to be striated. Acrilan has been manufactured in the past with a kidney-shaped cross section which showed up as a faint lumen in longitudinal view. Both fibers were therefore carried along with the striated category in parentheses.

Optical Properties (26–32)

Man-made fibers, with the exception of Arnel and glass fibers, can be considered as anisotropic (doubly refractive) crystalline solids, the "crystallites" within the fiber having been so oriented during the drawing process that the optic axis of the fiber is parallel to its long axis. The measurement of such optical properties as refractive indices (n_ϵ, n_ω), birefringence, sign of elongation, and optic sign would be expected to afford a valuable means for the identification of man-made fibers.

Utilization of the optical properties mentioned above for the purposes of the identification scheme requires *any one* of the following combinations:

1. polarizing microscope with compensators (quartz wedge and 1st order red plate)

2. compound microscope with two polaroid sheets and self-constructed eyepiece compensator (26)
3. polarizing microscope with set of calibrated immersion liquids (n = 1.460 — 1.720)
4. compound microscope with two polaroid sheets and set of calibrated immersion liquids (n = 1.460 — 1.720)

Measurements with use of compensators: The *sign of elongation* is an arbitrarily determined property of anisotropic substances which depends on the relative planes of vibration for the fast and slow rays in the substance as compared with the fast and slow rays in the compensator. For fibers, if the slow ray in the compensator vibrates *parallel* to the long direction of the fiber, by definition the sign of elongation is positive; and if the slow ray in the compensator vibrates *perpendicular* to the long direction of the fiber, it is negative.

Birefringence is a measure of the double refraction of anisotropic substances. Man-made fibers are uniaxial and will exhibit two refractive indices; n_ϵ, where the vibration direction of light coming from the polarizer is *parallel* to the fiber axis and n_ω, where the vibration direction of the light is *perpendicular* to the fiber axis. The birefringence depends on the difference in velocities between the slow and fast rays (retardation) and the thickness of the fiber through which they travel,

$$n_\epsilon - n_\omega = \frac{R}{D}$$

where R is the retardation and D is the thickness of the fiber, both measured in the same units, usually millimicrons.

Direct measurement of the sign of elongation and birefringence is not nearly so precise as actual determination of the refractive indices of the fibers (see below). Some difficulties were encountered with exceptionally fine fibers such as cuprammonium rayon and Fortisan, with heavily striated fibers such as viscose rayon, and with heavily dyed samples. Furthermore, the essentially cylindrical shape of all fibers results in the appearance of more than one polarization color across the fiber. Despite these limitations it was possible, in the large majority of cases, by employing the sign of elonga-

tion, birefringence, and six different refractive index separations to further subdivide both groups of fibers (striated and non-striated) to the point where 9 of the fibers were identified. By including a diameter measurement in the case of Fortisan and viscose rayon, it can be seen that for 11 fibers it is possible to arrive at a point in the scheme where the fiber has been identified *without removing* it from its original mount.

Measurements of refractive indices: The refractive indices of uniaxial crystalline substances can be determined quite simply by immersion methods such as the Becke line method or the oblique illumination method. Measuring the refractive indices at two extinction positions of the crystal 90° apart will determine the values of n_ϵ and n_ω. Man-made fibers exhibit parallel extinction and because of their long optic axis these positions can be achieved by merely aligning the fiber parallel to one of the cross hairs. With a polarizing microscope having the polarizer set in its usual position (direction of vibration of light through polarizer is in vertical direction) n_ϵ is measured with the fiber axis parallel to the vertical cross hair, and n_ω is measured with the fiber axis parallel to the horizontal cross hair. The refractive indices can be determined with a probable error of $\pm$ .003 (greater for heavily dyed fibers) using white light, calibrated liquids in intervals of .002, and by correcting for temperature. $n_\epsilon - n_\omega$ will then give the optic sign and birefringence of the fiber measured (for purposes of measurements on fibers, sign of elongation and optic sign can be considered as equal).

The measurement of the refractive indices of a single fiber does require a certain amount of technique. About ⅔ of the fiber is covered with a small broken piece of cover slip. A *very small* amount of immersion liquid, just enough to cover the fiber, is touched to the slide and allowed to creep underneath the cover slip. (A liquid of refractive index equal to 1.520 is suggested as a starting point.) After the necessary observations are made under the microscope, any excess liquid is soaked up with filter paper and the fiber removed from beneath the cover slip by grasping the protruding end. The same procedure as before is now followed, using

another broken piece of cover slip and a different immersion liquid.

For the purposes of the identification scheme either the direct measurements of the optical properties with compensators or measurement of the refractive indices with calibrated immersion liquids differing from each other by as much as .005 will be sufficiently accurate to ensure results. A list of miscible organic liquids which will cover the values required in the scheme, as well as provide a range of mixtures suitable for confirmatory refractive index measurements, is shown in Table 3.

TABLE 3. Liquids for Refractive Index Measurements

Liquid	Refractive Index
Amyl Alcohol	1.409
Pentachloroethane	1.502
Ethylene Bromide	1.535
Nitrobenzene	1.549
Bromoform	1.595
alpha-Bromnaphthalene	1.66
Methylene Iodide	1.737

The optical properties determined for the 18 man-made fibers studied are summarized in Table 4.

Melting Point (25, 33)

Many of the man-made fibers possess melting points over a short enough range so that their measurement is of value for identification purposes. To increase the usefulness of melting point as an identification property, eutectic melting temperatures of fibers with p–nitrophenol (m.p. 113–114° C.) as a reference compound have been used in order to achieve melting of the fiber before its decomposition temperature is reached.

Melting points, including temperatures for eutectic melting with p–nitrophenol, are listed in Table 5. In order to shorten the range over which melting takes place, it has been sug-

TABLE 4. Optical Properties of Man-made Fibers

Fiber	Number Studied: undyed to medium	Number Studied: medium to dark	Refractive Indices undyed to medium: n_ϵ	Refractive Indices undyed to medium: n_ω	Refractive Indices medium to dark: n_ϵ	Refractive Indices medium to dark: n_ω	Birefr. and Sign of Elong.
Acetate	6	4*	1.478 ± .006	1.481 ± .011	1.476 ± .006	1.479 ± .013	+.003
Acrilan	7	12	1.517 ± .010	1.520 ± .011	1.519 ± .030	1.522 ± .031	—.003
Arnel	4	3	1.472 ± .004	1.472 ± .004	1.472 ± .018	1.472 ± .018	none
Cupra. rayon	19	6	1.558 ± .008	1.528 ± .008	1.556 ± .010	1.533 ± .016	+.028
Dacron	7	3	1.711 ± .011	1.541 ± .012	1.714 ± .014	1.548 ± .013	+.168
Darlan	2	1	1.465 ± .006	1.473 ± .007	1.492 ± .006	1.499 ± .007	—.008
Dynel	5	—	1.533 ± .004	1.531 ± .003	—	—	+.002
Fortisan	10	2	1.569 ± .008	1.520 ± .004	1.570 ± .020	1.523 ± .023	+.048
Glass	10**	—	1.549 ± .015	1.549 ± .015	—	—	none
Nylon	8	7	1.575 ± .007	1.520 ± .006	1.579 ± .010	1.524 ± .007	+.055
Orlon	16	3	1.518 ± .006	1.520 ± .008	1.520 ± .005	1.521 ± .005	—.002
Polyacrylo-styrene	1	—	1.560 ± .003	1.572 ± .003	—	—	—.012
Polyethy-lene	1	1	1.574 ± .003	1.520 ± .003	1.574 ± .003	1.525 ± .003	+.052
Saran	2	1	1.601 ± .004	1.609 ± .004	1.596 ± .003	1.606 ± .003	—.009
Verel	5	—	1.535 ± .003	1.539 ± .003	—	—	—.004
Vicara	6	8*	1.538 ± .005	1.536 ± .005	1.541 ± .009	1.538 ± .008	+.002
Vinyon HH	1	—	1.527 ± .002	1.525 ± .002	—	—	+.002
Viscose rayon	11	6	1.558 ± .008	1.528 ± .010	1.562 ± .018	1.529 ± .011	+.031

* one sample was so heavily dyed as to appear opaque with transmitted light
** includes four samples of Fiberfrax ceramic fiber

gested that the fiber be mounted in a high boiling point inert liquid such as Silicone Oil 710 (25).

Melting point determinations on a single fiber are carried out on a short length of fiber, 1–2 mm. or less, which has been cut from the original fiber used in the microscopic examination and optical property measurements. It has been found advantageous to cut the fiber by grasping one end with a pair of fine-tipped forceps and cutting the short length from the other end with a scalpel or razor blade held so as to make a very small angle with the surface on which the fiber is lying. This prevents both fiber lengths from being lost during the cutting process. The fiber is then covered with a cover slip on the melting stage, and the temperature of the melting point apparatus is allowed to rise at a rate of no more than 3°/minute. Points at which the fiber first appears to shrink or melt and at which it is completely melted are noted, as well as other features such as charring, discoloring, or swelling. The observations are best made at a magnification of about 50X.

TABLE 5. Melting Point Data for Man-made Fibers

Fiber	Melting Point (in air) °C	Melting Point (eutectic) °C
Acetate	245–260°	swelling over 80°; melts at 88–92°
Acrilan	—	much shrinking; melts at 106–115°
Arnel	290–300°	96–100°
Dacron	250–270°	110–115°
Darlan	—	shrinking at 101–104°; melting complete at 108°
Dynel	—	shrinking at 85–90°; melting complete at 95–100°
Nylon 6	215–220°	——
Nylon 66	251–260°	——
Orlon	—	103–106°; melting complete by 112°
Polyethylene	110–138°	forms immiscible melt with p-nitrophenol
Verel	—	92–95° (sharp)
Vinyon HH	125–135°	——

The eutectic melting points are determined by adding a small amount of lightly crushed p–nitrophenol to the melting

stage together with the fiber. The cover slip is then gently rotated with a pencil eraser to further break up large aggregates of the p–nitrophenol and distribute it more evenly about the fiber. A particle size of roughly 1–5 times the fiber diameter is preferred.

Solubility

The literature abounds with solvents for man-made fibers, particularly for the synthetics. However, many of these are of value principally for quantitative work on fiber blends and require either prolonged extraction or elevated temperature before they actually effect solution of the fiber. For the purposes of identifying a single fiber, the solvents listed in Table 6 have been chosen not only for their relative selectivity but also because they were found to dissolve the fiber rapidly at room temperature and without repeated application.

TABLE 6. Solvents for Man-made Fibers

Fiber	Acetone	Dimethyl-formamide	HCl (1:1)	HNO_3 (conc.)	Chloro-form
Acetate	S	S	NS	S	NS–X
Acrilan	NS	NS	NS	S	NS
Arnel	S	S	NS	S	S
Cuprammonium rayon	NS	NS	NS	X	NS
Dacron	NS	NS	NS	NS	NS
Darlan	NS	S	NS	S	NS
Dynel	X	S	NS	S	NS
Fortisan	NS	NS	NS	X	NS
Glass	NS	NS	NS	NS	NS
Nylon	NS	NS	S	S	NS
Orlon	NS	NS	NS	S	NS
Polyacrylostyrene	S	S	NS	S–X	S
Polyethylene	NS	NS	NS	NS	NS
Saran	NS	NS	NS	NS	NS
Verel	NS	S	NS	S	NS
Vicara	NS	NS	NS	NS–X	NS
Vinyon HH	S	S	NS	NS	S
Viscose rayon	NS	NS	NS	X–S	NS

S = soluble
NS = not soluble
X = attacked slowly

As with the melting point and refractive index determinations, solubility tests on a single fiber can be carried out with relative ease. A very short length at one end of the fiber is covered with a piece of broken cover slip; and a very small drop of the solvent is allowed to creep underneath. The action of the solvent can be observed readily with the aid of a stereo binocular microscope.

Density (8, 16, 26, 33, 34)

Although slight variations in the density of man-made fibers are to be expected in the case of heavily delustered samples and also with some dyed samples, the property is still of value from the standpoint of a confirmatory test. It would appear that a difference of 0.2, and in many cases a difference of 0.1, can be detected in a single unknown fiber. Density values for the 18 man-made fibers included in the scheme are given in Table 7.

Density measurements can be made on a single fiber by using a calibrated xylene-bromoform gradient. However, this leads to difficulty in recovering the fiber. A better method of determining the density of a single fiber, which is accurate enough for the purposes here, is to set up a series of 75 mm. x 22 mm. test tubes, each filled with a liquid of different density in 0.05 intervals from 0.90 to 1.75. The recovery of a single fiber from such a test tube is a relatively simple matter.

TABLE 7. Density of Man-made Fibers

Fiber	*Density*	*Fiber*	*Density*
Acetate	1.3	Nylon	1.1–1.2
Acrilan	1.1–1.2	Orlon	1.1–1.2
Arnel	1.3	Polyacrylostyrene	1.1
Cuprammonium rayon	1.5	Polyethylene	0.9
Dacron	1.4	Saran	1.7
Darlan	1.1	Verel	1.1–1.2
Dynel	1.3	Vicara	1.2–1.3
Fortisan	1.5–1.6	Vinyon HH	1.3–1.4
Glass	2.5	Viscose rayon	1.5

Diameter

The diameter of a man-made fiber, as measured with a calibrated ocular micrometer at a magnification of 440X (preferably when mounted in a suitable liquid such as amyl alcohol), is often of value in identification. Some fibers, such as Fortisan and cuprammonium rayon, at this writing are manufactured only in very fine denier. Others, such as Saran and Polyethylene, are found only in relatively large monofilament form. The range and mode for the diameters of the 18 fibers studied are given in Table 8. Also listed are the number of delustered vs. bright fibers, another point which is often of assistance as a confirmatory property.

TABLE 8. Diameter and Delustering of Man-made Fibers

Fiber	Diameter		Delustrant		
	range (microns)	mode (microns)	dull	bright	questionable
Acetate	18–175	21	45	39	9
Acrilan	16–28	18	45	1	2
Arnel	18–28	21	10	13	3
Cuprammonium rayon	10–17	11	11	25	1
Dacron	12–21	17	45	2	—
Darlan	14–30	21	3	—	—
Dynel	18–35	24	—	8	—
Fortisan	7–11	9	—	13	28
Glass	1–22	5	—	33	—
Nylon	14–48	17	49	31	1
Orlon	18–34	23	55	—	—
Polyacrylo-styrene	—	—	—	1	—
Polyethylene	—	—	—	1	1
Saran	—	—	—	3	—
Verel	18–32	24	3	2	—
Vicara	17–35	18	16	—	—
Vinyon HH	18–25	—	—	1	—
Viscose rayon	10–500	21	39	57	2

Results:

The identification scheme for man-made fibers as presented has been found successful in all cases tested. Both dyed

and undyed, delustered and non-delustered, staple and filament unknown samples have been identified on the basis of a single fiber, usually less than ¼ inch in length. It is realized that there might be an occasional very deeply dyed fiber (black) which could not be classified as to microscopic characteristics or optical properties because of its opaqueness. In such a case those properties such as melting point, solubility, and density which are unaffected by dyeing must be utilized. "Stripping" the dye has not proved successful in most cases, since stripping agents as a rule are likely to attack the fiber and affect many of its properties.

KEY FOR THE IDENTIFICATION OF MAN-MADE FIBERS

1.a.* Upon microscopic examination of longitudinal section fiber appears round, relatively smooth. Some surface "pitting" and/or fibrillation may be present, but no longitudinal striation(s) is seen. When focussing down from top center of fiber, both outside edges are seen to come into focus at same time.

2.

b.* Upon microscopic examination of longitudinal view fiber shows one or more striations (or "lumen"). Diameter may show some variability. When focussing down from top center of fiber, outside edges may not come into focus at same time.

10.

2.a. Sign of elongation, as determined between crossed nicols with compensators (or optic sign as determined by $n_\epsilon - n_\omega$), is *positive*.

3.

b. Sign of elongation is *negative*.

8.

c. Fiber is not birefringent; i. e., it will not transmit light between crossed nicols at 45° position (or birefringence is less than .001).

9.

3.a. Birefringence, as determined directly from thickness of fiber and its polarization color (or from $n_\epsilon - n_\omega$) is less than .015.

4.

b. Birefringence is between .015 and .048.

CUPRAMMONIUM RAYON

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.555
n_ω 1.527 (birefringence: + .028)

---

*Determination of microscopic category into which fiber belongs should not be made without reference to standard samples.

(b) diameter: 10–17μ
(c) density: 1.5

5.

c. Birefringence is greater than .048.

4.a. Fiber is readily soluble in acetone, dissolving immediately upon contact with solvent.

VINYON HH

Confirmatory tests:
(a) melting point (air): 125–135°C (softens at about 75°C)
(b) solvent: chloroform
(c) refractive indices:
n_ϵ 1.527
n_ω 1.525 (birefringence: + .002)
(d) density: 1.3–1.4

b. Fiber is not soluble in acetone.

VICARA

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.539
n_ω 1.536 (birefringence: + .003)
(b) density: 1.2–1.3

5.a. n_ϵ (fiber aligned parallel to vertical cross hair) is greater than 1.66 (refractive index of alpha-bromnaphthalene).

DACRON

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.712
n_ω 1.540 (birefringence: + .172)
(b) melting point:
(in air): 250–270°C
(eutectic): 110–115°C
(c) density: 1.4

b. n_ϵ is less than 1.66.

6.

6.a. Fiber is soluble in 90% phenol.

7.

b. Fiber is not soluble in 90% phenol.

POLYETHYLENE

Confirmatory tests:
(a) density: 0.9
(b) melting point:
(in air): 110–138°C
(eutectic): forms immiscible melt with p–nitrophenol
(c) refractive indices:
n_ϵ 1.574
n_ω 1.522 (birefringence: + .052)

7.a. Melting point (in air) is greater than 240°C.

NYLON 66

Confirmatory tests:
(a) solvents:
1.1 hydrochloric acid
80% formic acid
(b) refractive indices:
n_ϵ 1.578
n_ω 1.520 (birefringence: + .058)
(c) density: 1.1–1.2

b. Melting point (in air) is less than 240°C

NYLON 6

Confirmatory tests:
—see 7.a.

8.a. n_ω (fiber aligned parallel to horizontal cross hair) is greater than 1.595 (refractive index of bromoform).

SARAN

Confirmatory tests:
(a) Melting point:
(in air): shrinks at about 160°C, melts at 169–174°C
(eutectic): decomposes with evolution of gas at about 155°C
(b) refractive indices:
n_ϵ 1.600
n_ω 1.608 (birefringence: — .008)
(c) density: 1.7

b. n_ω is between 1.595 and 1.549.

POLYACRYLOSTYRENE

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.560
n_ω 1.572 (birefringence: — .012)
(b) solvent: dimethylformamide

c. n_ω is less than 1.549 (refractive index of nitrobenzene).

ACRILAN

Confirmatory tests:
(a) melting point (eutectic): 106–115°C
(b) refractive indices:
n_ϵ 1.518
n_ω 1.522 (birefringence: — .004)
(c) density: 1.1–1.2
(d) solvent: conc. nitric acid

9.a. Refractive index is greater than 1.535 (refractive index of Ethylene Bromide).

GLASS

Confirmatory tests:
(a) density: 2.5

(b) diameter: 1–11μ
(c) refractive index: 1.550

b. (Refractive index is less than 1.535).

(VINYON HH)

Confirmatory tests:
—see 4.a.

10.a. Sign of elongation, as determined between crossed nicols with compensators (or optic sign as determined by $n_\epsilon - n_\omega$) is *positive*.

11.

b. Sign of elongation is *negative*.

16.

c. Fiber is not birefringent; i. e., it will not transmit light between crossed nicols at the 45° position (or birefringence is less than .001).

18.

11.a. Birefringence, as determined directly from thickness of fiber and polarization color (or from $n_\epsilon - n_\omega$) is greater than .015.

12.

b. Birefringence is less than .015.

14.

12.a. Average diameter of fiber is greater than 13μ.

VISCOSE RAYON

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.558
n_ω 1.527 (birefringence: + .031)
(b) density: 1.5

b. Average diameter of fiber is less than 13μ.

13.

13.a. n_ϵ (fiber aligned parallel to vertical cross hair) is greater than 1.563.

FORTISAN

Confirmatory tests:
(a) diameter: 7–11μ
(b) refractive indices:
n_ϵ 1.569
n_ω 1.520 (birefringence: + .049)
(c) density: 1.5–1.6

b. (n_ϵ is less than 1.563)

(CUPRAMMONIUM RAYON)

Confirmatory tests:
—see 3.b.

14.a. Average refractive index is greater than 1.502 (refractive index of pentachloroethane).

DYNEL

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.533
n_ω 1.531 (birefringence: + .002)

(b) microscopic: fiber often shows twist with very irregular diameter
(c) melting point (eutectic): much shrinking at 85–90°C; melting complete by 95–100°C
(d) solvent: dimethylformamide
(e) density: 1.3

b. Average refractive index is less than 1.502.

15.

15.a. Melting point (in air) is less than 275°C.

ACETATE

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.480
n_ω 1.477 (birefringence: + .003)
(b) solvents: acetone
glacial acetic acid
(c) melting point (air): 245–260°C
(d) density: 1.3

b. (Melting point is greater than 275°C)

(ARNEL)

Confirmatory tests:
—see 18.a.

16.a. Average refractive index is less than 1.502.

DARLAN

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.480
n_ω 1.489 (birefringence: — .009)
(b) melting point (eutectic): shrinking at 101°C; melting complete by 108°C
(c) solvent: dimethylformamide

b. Average refractive index is greater than 1.502.

17.

17.a. Fiber is readily soluble in dimethylformamide.

VEREL

Confirmatory tests:
(a) melting point (eutectic): 92–95°C (sharp)
(b) refractive indices:
n_ϵ 1.535
n_ω 1.539 (birefringence: — .004)
(c) density: 1.1–1.2

b. Fiber is not soluble in dimethylformamide.

ORLON
(ACRILAN)

Confirmatory tests:
(a) refractive indices:
n_ϵ 1.518
n_ω 1.524 (birefringence: — .002)
(b) melting point (eutectic): swelling at 103–106°C; melting complete by 112°C
(c) solvent: conc. nitric acid
(d) density: 1.1–1.2

18.a. Melting point (in air) is greater than 275°C

ARNEL

Confirmatory tests:
(a) melting point (air): 290–300°C
(b) refractive index: 1.472
(c) solvent: acetone
(d) density: 1.3

b. (Melting point is less than 275° C in air)

(ACETATE)

Confirmatory tests:
—see 15.a.

A scheme for the identification of 18 man-made fibers manufactured commercially in the United States at the end of 1956 is presented. The scheme, including confirmatory tests, has been tested with unknown samples and has proved successful for the identification of a single fiber, including heavily dyed and heavily delustered samples. Although it is realized that the scheme might be difficultly adaptable in the case of a very deeply dyed fiber, particularly black, the occurrence of such deeply dyed fibers was found to be less than 5%. For this reason it is believed that the scheme has practical application in the field of Criminalistics for the identification of man-made fibers; which, more often than not, will turn up as trace evidence in the form of a single fiber.

It must be understood that the field of man-made fibers, particularly at the present time, is one in which change is extremely rapid. Many of the fibers studied here can be expected to be altered as new manufacturing processes are developed; changes which in most instances will also affect the properties used in the identification scheme presented here. Furthermore, many new fibers will undoubtedly be discovered in the future. It is therefore considered imper-

ative that the scheme be reviewed and revised, if necessary, every 2–4 years.

During the progress of the research reported here it was noted that, although the fibers generally fell into different categories which were valuable for their identification, many of the samples within one type would vary enough, especially as to optical properties, to suggest that many of the tests carried out in the scheme for identification of a fiber type should also be of value for the comparison of fibers to determine whether or not they could have originated from the same textile material. Such tests, being applicable to a single fiber, would be expected to increase the probability of a fiber "match" beyond the value now possible with a fiber type and color comparison.

The following additional research is recommended:

1. Incorporation of the scheme for the identification of man-made fibers into a larger scheme to include natural fibers.
2. Periodic review and revision of the scheme for man-made fibers to include new fibers and older fibers whose properties may have been altered by changes in manufacturing processes.
3. Research into the relative frequencies of occurrence of all fiber types, particularly the man-made group.
4. Statistical survey of the various fiber properties reported here in an effort to determine their value in the comparison of fibers.

The authors are indebted to W. L. Johnson and W. H. Storer for their assistance in gathering data for this study, as well as the following list of manufacturers who have contributed fibers for experimental purposes:

American Bemberg Corp.
American Cyanamid Co.
American Viscose Corp.
B. F. Goodrich Co., Textile Fibers Division
Carbide & Carbon Chemicals Co., Textile Fibers Dept.
Carborundum Co., Refractories Division
Celanese Corporation of America
Chemstrand Corp.
Courtalds, Inc.

Dawbarn Brothers, Inc.
E. I. du Pont de Nemours & Co.
Firestone Plastics Co.
Hartford Rayon Corp.
Lus-Trus Extruded Plastics, Inc.
National Aniline Division, Allied Chemical and Dye Corp.
National Plastics Products Co.
New Bedford Rayon Co.
Owens-Corning Fiberglas Corp., Textile Products Division
Reeves Brothers, Inc.
Tennessee Eastman Company, Eastman Chemical Products, Inc.
Virginia-Carolina Chemical Corp., Fiber Division

REFERENCES

1. Meadows, B.: Trends in the Consumption of Fibers in the United States, 1892–1948, Agr. Econ. Bull. 89, U. S. Dept. of Agriculture, 1950.
2. Love, J.: From Wonder Fiber to Wonder Fabric—A Challenge to Management. Leaflet, Am. Assoc. Textile Chem. Colorists, Burlington Mills Corp., 1951.
3. Bendigo, C. W.: American Society for Testing Materials. June, 1952. News Release, American Cyanamid Co., New Products Division.
4. A. A. T. C. C.: Tentative Test Method 20–47. Yearbook, 1951.
5. A. S. T. M.: Standard Methods of Identification of Fibers in Textiles. A. S. T. M. Designation D276–49.
6. Tentative Textile Specification 13–1948: Identification of Textile Materials. J. Textile Institute, 39:S1–10, March, 1948.
7. Krauss: Matthews' Textile Fibers. 6th Ed. 1095–1128, 1954.
8. The Textile Institute: Identification of Textile Materials. 3rd Ed., 1951.
9. Fisher, D. C., and Roberts, E. D.: Analysis of Staple Fiber Mixtures. Textile Research J., 22:509, 1952.
10. Ford, J. D., and Roff, W. J.: Identification of Textile and Related Fibers. J. Textile Institute, 45:8, 1954.
11. Lundegard, M. and Roseberry, E. D.: A Qualitative Analysis of the Synthetic Fibers. Am. Dyestuff Reptr. 43:4, 1954.
12. Sassi, D.: A Rapid Method of Identification of Textile Fibers in Blends. Am. Dyestuff Reptr. April, 1953.
13. E. I. du Pont de Nemours & Co.: Identification of Fibers. Tech. Information Bulletin X-12, 1956.
14. Donovan, J. D., Beegan, J. A., and Hummel, G. H.: Identification of Textile Fibers by Dye Staining Techniques. Textile Research J. 26:3, 1956.
15. Koontz, F. H. and Wilson, W. R.: Identification of Synthetic Fibers. Special Publication, American Viscose Corporation, 1951.
16. Bergh, A. K.: Some Aspects Relative to the Identification of Synthetic Fibers. Int. Crim. Pol. Rev. No. 91, 246–256, 1955.
17. Royer, G. L.: Identification of Synthetic Fibers by Microscopical and Dye Staining Techniques. Calco Tech. Bull. No. 831, 1952.

18. Fox, K. R., and Finch, R. B.: Simplified Method for the Determination of Refractive Indices of Textile Fibers. Textile Research, 11:62–71, 1940.
19. Heyn, A. N. J.: Observations of the Birefringence and Refractive Index of Synthetic Fibers with Special Reference to Their Identification. Textile Research J. 22:513–522, 1952.
20. Heyn, A. N. J.: The Identification of Synthetic Fibers by Their Refractive Indices and Birefringence. Textile Research J. 23:246–251, 1953.
21. Norwick, B.: The Rapid Identification of Fibers by the Christiansen Effect. Textile Research J. 23:259–261, 1953.
22. Douglass, Pritchard C., and Crossmon, G. C.: Examination of Textile Fibers by the "Dispersion Staining" Method. Textile Research J. 19:644–646, 1949.
23. Allied Chemical and Dye Corp.: Color Contrast—Caprolan versus Nylon 6, 6. Technical Report D-17949, 1956.
24. Heckert, W. W.: Synthetic Fibers. J. Chem. Ed. 30:166, 1953.
25. Grabar, D. G., and Haessly, R.: Identification of Synthetic Fibers by Micro Fusion Methods. Anal. Chem. 28:10, 1956.
26. Heyn, A. N. J.: Fiber Microscopy. Interscience Publishers, Inc., New York, 1954.
27. Wahlstrom, E. E.: Optical Crystallography. 2nd Ed. John Wiley and Sons, Inc., 1951.
28. Hartshorne, N. H. and Stuart, A.: Crystals and the Polarizing Microscope. Arnold, London, 1934.
29. Winchell, A. N.: Elements of Optical Mineralogy. Part I. 5th Ed., John Wiley and Sons, Inc., New York, 1937.
30. Chamot, E. M. and Mason, C. W.: Handbook of Chemical Microscopy. Vol. II, John Wiley and Sons, Inc., New York, 1931.
31. Allen, R. M.: Practical Refractometry by Means of the Microscope. R. P. Cargille Laboratories, Inc., 1954.
32. Food and Drug Administration: Microanalysis of Food and Drug Products. Circular No. 1, pages 29–44.
33. London, M.: 1955 Synthetic-Fiber Table. Textile World, 43:1955.
34. E. I. du Pont de Nemours & Co.: The Specific Gravity of Textile Fibers, Tech. Information Bull. X–35, 1955.
35. Mauersburger, H. R.: Matthews' Textile Fibers. 6th Ed. John Wiley and Sons, Inc., New York, 1954.
36. Fieser, L. F. and Fieser, M.: Organic Chemistry. 2nd Ed. D. C. Heath and Co., Boston, 1950.

488 N. Wabasha Street
St. Paul 2, Minnesota

Mechanical Injuries of the Heart and Great Vessels*

*Gale E. Wilson, M.D.,** Seattle, Washington*

Introduction

Damage to the heart and the great vessels by penetrating wounds has been recognized since long before accurate written records were kept. Recognition of injury by blunt force dates back at least to the year 1676 when a case of contusion of the chest resulting in damage to the right auricle was reported in an 8-year-old boy who survived for one month after the injury (1). Yet, since that time we have continued to ignore facts, and have continued to teach that the heart and great vessels are well protected within the bony and cartilaginous thoracic cage, and thus are not often subject to injury, either by direct or indirect trauma. As late as 1956, White (2) states that: "As a matter of fact the heart is a very mobile organ in the chest and is likely to escape injury, whether the trauma is penetrating or not; in reviewing cases of wounds of the heart, Elkin (1938) noted that in his experience only 2% of penetrating wounds of the chest injured the heart."

Also, White (2) states that: "When rupture of any sort comes by indirect violence, spontaneous heart disease is usually found to underlie the injury . . . . Sometimes, however, even when trauma does not seem great, clean cut rupture (usually linear tears) of heart wall or aorta may occur without any evidence of local disease at post mortem examination; such cases are to be explained by an unusual amount of strain exerted at the moment of full distension of heart chamber,

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 2, 1957, Chicago, Illinois.

** Chief Autopsy Surgeon and Pathologist, Office of the King County Coroner, Seattle, Washington.

aorta, or valve cusp, the tissue in question being perhaps congenitally weak."

A review of the recent literature shows that there is an ever-increasing interest in the effects of trauma, especially the non-penetrating types, upon the heart and great vessels, and an entirely new concept of injury to the contents of the thoracic cage has formed as a result of the studies of the so-called "acute flexion syndrome." Studies made during World War II have shown also that the "blast" or "concussion" syndrome may result in damage to the heart muscle, and also that many cases are either delayed in showing the damage, or that the individual may actually survive serious cardiac injury.

Numerous authenticated cases of contusion of the myocardium, penetrating wounds of the heart or aorta, or of disorders of rhythm have been recorded, and there is an increasing number of recoveries being reported. Likewise, there are more cases being reported of delayed evidence of injury, and of late complications such as pericarditis or aneurism ultimately resulting in death as much as 10 months later (3) with no aortic disease (atherosclerosis or medial necrosis) being demonstrable at autopsy.

In the clinical diagnosis and evaluation of cardiac or aortic injury there is a great medicolegal responsibility upon the part of the examining physician. As Halter (4) stated: "I am afraid that when those in the legal profession become acquainted with this entity, which they are rapidly doing, our previous difficulties with headache, backache and whiplash injuries to the neck will appear relatively simple. It therefore behooves all of us who handle the problem of trauma to consider the possibility of cardiac damage, record an evaluation of the cardiovascular system and obtain diagnostic studies and cardiac consultation whenever indicated. In this way we can best serve and protect the patient, the insurance carrier and ourselves."

Classification of Injuries

There is no very satisfactory way to classify injuries to the heart and great vessels. Some prefer to start with a system of "Immediately Fatal, Delayed Fatal and Non-Fatal." Others

divide the injuries into Penetrating and Non-Penetrating, and then proceed from there. Others begin with the causative factor such as Perforating Wounds, Lacerating Wounds, Contusions, etc.

A relatively simple classification, at least from the standpoint of description might be as follows:

I. Penetrating injuries:
   A. Of heart
   B. Of great vessels
      1. Vena cava superior
      2. Vena cava inferior
      3. Pulmonary artery
      4. Pulmonary veins
   C. Combinations of any of the above

II. Non-penetrating injuries:
   A. Of heart
   B. Of great vessels
   C. Combination of any of the above

III. Compression injuries:
   A. Without fractures of thoracic cage or spine
   B. With fractures
   C. Injuries due to inertia

Such a classification has many faults, but it serves for a basis of discussion.

I. Penetrating Injuries

A. *Of the heart:* These are injuries caused by stabbing, piercing or tearing, or by the penetration of a missile or fragment. They are of course quite commonly seen in every emergency hospital and autopsy room. As White (2) states, the heart is mobile in the thoracic cage and hence likely to escape injury, even with penetrating injuries. To a certain extent this is true, for with semi-blunt instruments or large caliber-low velocity missiles there is a tendency for the heart to be only contused or "nicked" rather than penetrated, unless the angle of incidence is less than about 30 degrees from the verticle. This ability to escape penetration is due in large part to the surface convexity, but also to the thickness and resist-

ance of the muscular wall which offers a greater deflecting force, and even the serous quality of the epicardium is a factor in deflecting a missile. However, the mere presence of the protecting envelope, the pericardium, also sharply restricts the mobility of the organ, and thus renders it more susceptible to injury than it would be if entirely free. Likewise, when hemorrhage occurs into the pericardial sac, the resulting tamponnade curtails the ability of the heart to perform its work. If the bleeding is rapid, not much more than 300 to 400 ml. of fluid can be tolerated, but if the accumulation is slow (as is sometimes seen in hydropericardium) as much as 1 liter of fluid may be present before a fatal termination. In many cases of penetrating wound of the heart or great vessels the pericardium is opened, so that the blood can escape into the pleural cavity. Gradwohl (5) states that the total capacity of each pleural cavity is about 6 pints, and if the bleeding is slow such a volume of blood has been aspirated. On the other hand, in rapid loss of blood, 2½ to 3 pints appear to be the maximum compatible with life. Mediastinal shift may also contribute to an early death.

In November of 1956 we had the opportunity to perform an autopsy upon the body of a white male aged 56 years who was found in his hotel room with a stab wound of the mid-right chest. He refused to tell how the wound had been sustained, and maintained his silence until death intervened 10 days later. At autopsy there was a stab wound 20 mm. long lying obliquely 3.5 cm. to the right of the midsternal line and centered over the 4th right intercostal space. The weapon had been a long, narrow bladed knife which penetrated to a total depth of 11 cm. (4⅜ inches), nicking the anterior edge of the right lung, penetrated the pericardium just in front of the hilus of the right lung, and entered the anterior surface of the midportion of the right atrium. This wound was approximately 5 mm. long and closed by fibrin and clot, with an acute generalized fibrinous pericarditis with some 75 ml. of clot mixed in with the fibrin on the surface of the heart, and when the fibrin was wiped away the wound in the atrium began to bleed freely. No mural thrombus was found.

Grastnopal and Mannix (6) reported two cases of "thru and thru" stab wounds of the heart. One of these cases was

a 20-year-old white male who was stabbed. He was given 2 units of plasma, 5 units of blood, then 3 more units of blood, which elevated his blood pressure sufficiently so that he could be taken to surgery, whereupon his wounds on both the anterior and posterior walls of the ventricle were sutured and he left the hospital on the 25th day, apparently cured. Their second case bled more rapidly and expired on the operating table.

Lawrie (11) reported a case in 1955 of a 22-year-old male with a stab wound of the left ventricle. At operation 1.7 liters of blood and clot were removed from the pericardium, the wound was sutured and he left the hospital cured in 4 weeks.

Regardless of the ultimate outcome of penetrating wounds, the pathologist is often the witness in court, to whom is put the question: "Now doctor, just how far could a man in this condition, or with the condition as you found it at autopsy, run, or be capable of locomotion?" This might be the crucial question. Davidson and Fiddes (7) reported the case of a stab wound of the anterior wall of the heart with the right ventricle and anterior cusp of the tricuspid valve punctured, with the victim being considered drunk and who walked a total of 600 yards within a period of 20 minutes before he collapsed. He expired in 1½ hours. Glaister (9) reported a young male with a penetrating wound of the left ventricle who pursued his assailant some 40 or 50 yards, and Gonzales (10) describes a young male with a stab wound of the heart who crossed a street and climbed two flights of stairs before collapsing.

What might be called "oddities" among penetrating injuries to the heart are such things as perforation from a foreign body in the esophagus with perforation of the gullet and then of the heart. An umbrella rib was used to produce an abortion and was suddenly "pulled" from the hands of the operator and disappeared up the vagina. At autopsy it was found to have penetrated the diaphragm and apparently the resultant contraction of the muscle carried it directly into the heart where it was practically transfixed. Hunt and Warren (12) in 1956 reported a most unusual case of perforation of the rectum by a mop handle, with penetration up to the heart, producing a 3 cm. tear in the right atrium and with survival for 11½ hours, including an exploratory laparotomy. How, or why the

mop handle entered the rectum was not explained. Birrell and Syme (13) describe a case of perforation of the esophagus and aorta by a piece of fly-wire.

B. *Penetrating Injuries of the Great Vessels:* Injuries to the vena cava superior, pulmonary artery, or the aorta, are generally the result of gunshot wounds or stabbing, and the vessels are all about equally fixed in position and equally susceptible to injury. In my experience, covering some hundreds of gunshot deaths, I have found that a woman who has never held a gun in her hand before, can almost invariably put a bullet either through the left ventricle, the pulmonary artery, or the aorta, or sometimes even through all three. Likewise, given a knife and the urge, she can instinctively put it right to the spot, generally going in through the 3rd and 4th left interspace and often going completely through the heart and nicking the aorta for good measure.

We had one case some years ago in which the right subclavian and innominate veins were ruptured during an open reduction for a fracture of the clavicle. In this case successful suture was done, a muscle graft put over the suture line, and a perfect recovery was made.

C. *Combination Injuries:* These of course are common, especially with stab wounds or large caliber missiles. The most unusual case in our office is that of two young men filling the oxygen tanks in an airliner from a large commercial high pressure tank. When the small tank exploded a piece approximately 10x12 inches blew off, and with partially curled edges it entered the chest of one of the men, shearing off ribs, trachea, carotid and innominate arteries and accompanying veins and came to rest with the words "nonshatterable" clearly visible in the fragment as it rested in the chest.

II. Non-penetrating Injuries

A. *Of the Heart:* Contusion of the myocardium is perhaps the simplest and the most often seen, and is the one which is most likely to involve recovery, with perhaps some ultimate cardiac disability which will bring the case into a compensation court.

In considering contusion, or any other lesion of the heart resulting from trauma, we must assume that the heart was

previously normal. If not, then we must admit that a previously diseased heart is more susceptible to injury, and especially so in the consideration of lesions associated with coronary artery disease.

The type of accident producing contusion of the heart muscle, without penetration of the chest, is generally (1) crushing of the chest, (2) a blow over the front of the chest, or (3) a fall from a height. One must remember that there need be no fracture of the bones of the thorax, nor any visible contusions, especially in the young person with a very elastic rib cage. Hawkes (14) reporting upon 7,000 fatal accident cases found 70 examples of fatal heart trauma with 10 of these having no fractures and in 7 cases there were no external marks about the chest.

Osborn (15) described 262 autopsies on fatal accident cases from the Derbyshire Royal Infirmary (England) and the coroner's mortuary, and found 19 cases with heart trauma, most of which alone would have likely been nonfatal. He noted that both the anterior and posterior surfaces of the heart showed contusions from direct violence, and also noted that there was a significant amount of bleeding on the posterior aspect of the right atrium near the inferior caval orifice which might well occasion disorders of rhythm and could be readily overlooked in the routine post-mortem examination.

When rupture of the heart occurs following contusion of the myocardium the post-mortem findings usually suggest that the rupture or tear in the wall begins in the endocardium and works outwards, which is of course natural enough with the internal pressure exerted, especially in the left ventricle.

I have seen one case of contusion of the myocardium with mild clinical symptoms immediately after the automobile accident, and with death nearly 9 months later at which time a large area of scarring with reddened edges and confined to the outer aspect and anterior surface of the left ventricle was found, with no evidence of coronary disease and no demonstrable occlusions.

When we take up the question of contusion of the coronary arteries, with or without resultant thrombosis and/or infarction, then we are indeed skating out onto rather thin ice. There is no anatomic reason why the anterior descending

coronary artery cannot be readily contused by direct force, especially if the artery is diseased. The formation of a subintimal hemorrhage lays the groundwork for a thrombus to form. It is very important in these cases to have a very thorough and complete clinical history. Moritz (16) has very aptly pointed out, that from the medicolegal standpoint coronary thrombosis after injury is rare, and that not only must there be positive evidence that the thrombus occurred in the immediate regions of the trauma, but also that the age of the thrombus must correspond with the duration of the interval between the injury and death. Just how far we can go in tying up injury to occlusion and infarction must depend upon each individual case, and is far beyond the scope of this paper. Barber (17) quotes Leinoff as describing a case of a 38-year-old man struck over the front of the chest by a wave while swimming, and being rolled up onto the beach. Coronary thrombosis developed the following day! To say that this was the result of contusion or trauma seems a little speculative.

The relationship of acute strain to coronary thrombosis is on even thinner ice. Kapp (18) analyzed 42 cases of coronary thrombosis following trauma or unusual effort. His criterion included (1) trauma, physical effort, or emotional strain, not compatible with the usual occupation or habits, occurring before coronary thrombosis and myocardial infarction, (2) cardiac symptoms appeared immediately after the alleged injury, or developed gradually and continuously during a few hours or days, and (3) diagnosis of the heart lesion was corroborated by ECG evidence. On the basis of these criteria a causal relationship between coronary thrombosis and trauma was established as definite in 13 cases, possible in 6, doubtful in 5 and nonexistent in 18.

Moritz (19) has diagrammed the results of direct injury to the heart by blunt and penetrating injuries, with the usual contusion, laceration, valvular avulsion, etc., and with the addition of "cardiac commotion" as a clinical finding. Transient disruptions of cardiac rhythm after a blow to the chest are not uncommon, and he concludes that: "There is no clinical, pathological, or experimental evidence to indicate the occurrence of any permanent ill-effects after nonfatal cardiac commotion." Fatal cardiac commotion may reveal little at

post-mortem examination, either grossly or upon microscopic examination, yet it is perhaps more common than we realize, especially in those cases with previous infarction and sudden overload.

The role of stress has also been diagrammed by Moritz (19), and includes the causal factors of exertion, pain, fear and anger, which in turn set off a pressor reaction. On the normal heart this results in a transient dilatation with recovery on resting. With coronary artery disease it may produce relative coronary insufficiency which may be transient, may produce transient or persistent evidence of myocardial ischemia, or immediate cardiac arrest. Or, the pressor reaction may produce hemorrhage into an atheromatous area of the coronary artery, with transient dilatation and recovery, or transient or persistent evidence of myocardial ischemia, or delayed thrombosis or immediate cardiac arrest. As in the case of cardiac commotion, there is no evidence to indicate that a pressor episode of this type produces any permanent damage to a normal heart.

The development of coronary insufficiency during shock is well established, and it is in this condition that infarction is prone to develop in the already ischemic myocardium with coronary atherosclerosis, and this type may develop in the deep endocardial layers without demonstrable thrombosis.

One of the newer forms of direct injury to the heart is contusion by direct trauma incurred during cardiac massage. Thomas (20) reported a case of massive contusion of the myocardium following massage, and nearly all of us have seen cases in which there is not only contusion of the myocardium, but also practically denudation of the epicardium. Sometimes it seems better that the individual did not survive, for they would certainly have been a "cardiac invalid" or suffer mental deterioration from cerebral anoxia. We have seen cases in which cardiac massage was attempted as an "emergency" using bare hands and a jackknife, and another in which a 6-year-old boy "expired" during a tonsillectomy. Cardiac massage in this case was kept up for two hours, after which time he maintained a reasonably good beat. He lived for five days, and at autopsy we found an acute fibrinous

pericarditis on the abraded heart, and also anoxic degeneration of the cerebral cortical cells.

Another type of stress and strain might be included at this point, with especial reference to rupture of the heart by electrical shock, not the explosive high voltage such as is seen in linesmen who come in contact with high tension lines, but the type that is seen as a complication of electroshock therapy. Such a case is reported by Malamud and Zhentlin (21) in the person of a large, obese female of 55 years of age who had received 21 electroshock therapy treatments, and after a normal appearing reaction she expired about 25 minutes after the 22nd treatment. The autopsy revealed a 350 gm. heart with a linear rupture of an infarct of the left ventricle. The infarct was judged to be 4 days old, and a left coronary artery occlusion was demonstrated.

Recently we have evolved a new type of injury, which like some of its predecessors ("ford fracture" of the wrist, "bumper fracture" of the knee joint, etc.) we credit to the automobile and call the "steering wheel injury." This type of injury is becoming more common as the angle of the steering wheel and steering column, size of the wheel, angle of body and increased speed with freely movable seats all combine to produce a perfect combination for crushing the midportion of the chest in sudden deceleration. The typical injury consists of a zone of contusion about 4 to 10 cm. in width centering about the middle of the sternum and generally with fracture of the sternum and/or ribs, although there are cases with no fractures. In either case extensive damage may be found to heart or great vessels.

In these compression cases considerable damage may result from relatively little trauma if the heart should happen to be in diastole (distended with blood) at the time of impact. In such a case one is very likely to find: (1) contusion of the anterior heart wall (generally in the region of the anterior longitudinal sulcus), (2) rupture of the interventricular septum, (3) rupture of the interatrial septum, (4) rupture of the right ventricle (generally parallel to the anterior longitudinal sulcus), (5) rupture of the anterior portion of the left ventricle, (6) rupture of a papillary muscle or valve, or (7) contusion of the opposite side of the heart by "contre-coup."

Closely related to the "steering wheel" injuries are other types of blunt force to the chest wall, with or without fractures. Such injuries are the so-called "blast injuries" reported in great numbers during World War II, including a group of cases of cardiac injury incurred when the chest was penetrated by a large caliber missile without actually touching the heart. We sometimes see rupture of the heart from "landing flat" in diving, and not infrequently we see cardiac injury from a blow to the chest by a falling stone, sack of cement, bale of hay etc., with no visible damage to the external structures.

B. *Non-penetrating Injuries of Great Vessels:* Rupture of the aorta is apparently much more common in compression injuries than is rupture of the heart. Strassman (22) reporting from the Office of the Chief Medical Examiner for New York City, over the period from 1936 to 1942, recorded 72 cases of traumatic rupture of the aorta, 59 of which died within one hour, and 51 of them were the result of automobile accidents. Of these 72 cases, in 40 of them the point of rupture was the isthmus, just to the left of the origin of the left subclavian artery.

In rupture of the aorta we have several factors operating more or less independently, but often they operate together to produce a combined type of injury. These may be described as:

1. Direct trauma, such as simple crushing of the chest, with rupture of the aorta.

2. Direct trauma from the opposite side, such as with fracture of the dorsal spine with dislocation of the vertebrae and consequent severing of the aorta at the level of dislocation. This type of injury is frequently seen in lumbermen and loggers who are struck in the lower back by a swinging log or load of lumber, but of course any trauma which will produce the bony dislocation can sever the aorta.

3. Indirect trauma, of which there are four types:

a. Direct injury from the pressure of the column of blood within the aorta, which is transmitted in accordance with Pascal's law, and which acts as a sort of battering ram with the blood set in motion by acceleration in the sagittal plane and sudden deceleration such as is frequently seen in aircraft accidents. In these cases the usual point of rupture is in the isth-

mus at or near the point of attachment of the ligamentum arteriosum. The old type of over-the-shoulder harness or safety belt was especially prone to produce this type of injury, although the same type of injury may be seen with the present conventional type of safety belt. Teare (23) reported upon the post-mortem examination of 28 persons killed in the crash of a passenger plane at the London airport. Of the 28 victims examined 8 had a rupture of the aorta, and three had rupture of the heart, all associated with fractures of the ribs or spine, and "Were in my opinion caused by acute flexion of the body over the safety belt." He also stated that in 25,000 other post-mortem examinations he had seen only three other traumatic ruptures of the aorta, one from an airplane crash and two from traffic injuries.

b. Indirect trauma in the sense that the injury is produced by the rapidity of deceleration which dislocates the aorta in the plane of former lines of force. If the individual is riding seated and is abruptly stopped, the aorta tends to fold forwards in the chest, being anchored by the great vessels above and the diaphragm below, thus tending to tear at or near the isthmus. If the body is traveling in a plane parallel to the long axis of the body (a body thrown head foremost from a crashed vehicle) then the aorta tends to buckle and twist, with the point of rupture tending to be either at the isthmus or just above the aortic valves. To this effect of buckling may be added that of the impact of the column of contained blood.

c. Indirect trauma produced by the inertia of the heart in a body suddenly propelled forwards from a relative resting position (just the reverse of the foregoing). Such a case is one we had some years ago of a middle-aged man whose little dog ran into the highway. The man ran after the dog, and just as he stooped to pick it up he was struck from behind by a fast moving car. The victim was propelled 60 feet forwards and about 10 feet laterally before landing, and was dead when picked up a few seconds later. There was not a mark to be seen upon the body, not even at the point of impact. At autopsy no fractures were found, but the heart, lungs, liver and a fragment of ascending aorta were all found impacted in the pelvis. We have seen rather similar cases in individuals who jump from high places (we have one bridge with a clearance

of 190 feet to the water), and in several of these the heart and aorta have been torn free, with no fractures of the ribs or spine. Others have shown a fracture dislocation of the spine with severance of the aorta.

d. Another form of rather indirect trauma which may injure the aorta is that which is produced when the upper extremity, especially the right one, is suddenly and forcibly put into extreme abduction and hyperextension, thereby putting a sudden severe pull upon the innominate artery (or the subclavian artery on the left side), which in turn produces a tear on the under side of the angle formed by the emerging branch and the main trunk. This may result in the vessel developing an aneurism at this point, or it may go on to simple rupture within a short time. We had one case in which a young man was trying to break up a jam in a rock crusher, using a crowbar through a small hole. Suddenly the bar was thrown upwards, with the man being jerked completely off his feet by his right arm with which he held onto the bar. No fractures were found, but within a few days he showed an increasing hematoma of the pectoral muscles and less than six months later he expired, and at autopsy an aneurism of the right innominate artery and right side of the arch of the aorta was found, ruptured, and with no evidence of arterial degeneration or medial necrosis being found in the surrounding arterial wall. Experimentally it is possible to demonstrate this phenomenon by placing marks on the aorta and innominate artery and then forcibly stretching the arm, with as much as 1 cm. of stretching showing between the pointer marks. If the arterial wall is at all diseased, then the likelihood of injury is greatly enhanced. Because of the greater size of the innominate artery, and the greater anchoring effect of the heart and pericardium on the right side, such an injury is more likely to show on the right than on the left side.

Injury to the pulmonary artery is less common, and most frequently is due to a crushing injury to the chest, with one or both lungs being torn at the hilus, with the tear extending into the pulmonary artery.

Personal Experience

In an effort to correlate our experience with that of other writers, we have gone through the records of the last 3,000 autopsies performed in the office of the King County Coroner, and while we feel that these present a reasonably accurate picture, we do admit that if a similar number had been taken from a period of 20 years ago, when there were fewer and slower automobiles, etc., the percentages might have been somewhat less. Our personal experience is presented in Table 1.

Table 1.—Occurrence of Traumatic Injuries to the Heart and Great Vessels as Found in 3,000 Autopsies Performed in the Office of the King County Coroner, Seattle, Washington

HEART:		
Ruptured infaret	8	
Traumatic rupture		
Automobile accident	15	
Accidental fall	6	
Crushing accident	3	
Airplane crash	1	
Stomping homicide	1	
Contusion of myocardium	6	
Stab wounds	12	
Gunshot wounds	18	
TOTAL TRAUMATIC:		62
AORTA:		
Spontaneous rupture (aneurism)	8	
Traumatic rupture	2	
Stab wounds	2	
Gunshot wounds	1	
TOTAL TRAUMATIC:		5
HEART and VESSELS:		
Heart and aortic rupture	2	
Heart and Sup. V. Cava. rupt.	2	
Heart and Inf. V. Cava. rupt.	1	
Heart completely avulsed	2	
TOTAL TRAUMATIC:		7
GREAT VESSELS ALONE:		
Sup. V. Cava.: acc. falls	3	
: stab wounds	1	
Inf. V. Cava.: stab wound	1	
Pulmonary Veins: gunshot	1	
TOTAL TRAUMATIC:		6
GRAND TOTAL:		80

Summary

A review of the literature pertaining to mechanical injuries of the heart and great vessels shows an increasing interest in such conditions, and an increasing number of such cases being reported. Steering wheel injuries in automobile accidents and acute flexion syndrome injuries in aircraft accidents account for an ever-increasing number of injuries to the heart and aorta.

Of the last three thousand autopsies performed by the writer there were 62 cases of traumatic injury to the heart, 5 to the aorta, 7 involving both heart and great vessels and 5 involving the great vessels alone, a grand total of 80 cases or an incidence of 2.6% of the total autopsies performed. Hence, it would seem that even though the thoracic cage appears designed to protect the heart and great vessels, they are still subject to considerable trauma, and actually, because of the immobilization produced by the pleura, pericardium and anchoring by the great vessels, the contents of the thoracic cage are especially susceptible to injury by certain types of force.

REFERENCES

1. Halter, Bert L.: Non-penetrating Trauma to the Heart. Am. J. Surg. 90:237–240, 1955.
2. White, Paul: Heart Disease, 4th ed., pp. 604–607. Macmillan, New York, 1956.
3. Hass, Geo. M.: Types of Internal Injuries of Personnel Involved in Aircraft Accidents. J. Aviation Med. 15:77–84, 1944.
4. Halter, Bert L.: Non-penetrating Trauma to the Heart. Am. J. Surg. 90:237–240, 1955.
5. Gradwohl, R. B. H.: Legal Medicine. C. V. Mosby Co., St. Louis, 1954.
6. Grastnopal, P., and Mannix, E. P., Jr.: Perforating (through and through) Stab Wounds of the Heart. Surgery, 37:840–847, 1955.
7. Davidson, J., and Fiddes, F. S.: Prolonged Activity and Movement After a Penetrating Stab Wound of the Heart. Brit. Med. J. 1:210–211, 1956.
8. Smith, S. A., and Cook, W. G. H.: Taylor's Principles and Practice of Medical Jurisprudence, 10th ed., pp. 1–696. J. & A. Churchill, London, 1948.
9. Glaister, John: Medical Jurisprudence, 9th ed. E. & S. Livingston, Edinburgh, 1950.
10. Gonzales, Thomas A., Vance, Morgan, Helpern, Milton, and Umberger, Charles J.: Legal Medicine, Pathology and Toxicology, 2nd ed., p. 341. Appleton-Century-Crofts, New York, 1954.

11. Lawrie, R. W.: Recovery After Penetrating Wound of the Heart. Brit. Med. J. 1:952–953, 1955.
12. Hunt, A. C., and Warren, R. P.: An Unusual Wound of the Heart. J. Forensic Med. 3:94, 1956.
13. Birrell, J. H. W., and Syme, W. A.: Report of Cases: Perforation of Esophagus and Rupture of Aorta Due to Piece of Fly-wire. Med. J. Australia, 1:247–249, 1954.
14. Hawkes, S. Z.: Traumatic Rupture of the Heart and Intrapericardial Structures. Am. J. Surg. 27:503–507, 1935.
15. Osborn, G. R.: Findings in 262 Fatal Accidents. Lancet, 2:277–284, 1943.
16. Moritz, A. R.: Pathology of Trauma, 2nd ed., Lea & Febiger, Philadelphia, 1954.
17. Barber, Hugh: The Effects of Trauma, Direct and Indirect, on the Heart. Quart. J. Med. New Series XIII, 52:137–167, 1944.
18. Kapp, Louis A.: Trauma in Relation to Coronory Thrombosis: A Clinical Study of 42 Cases of Coronary Thrombosis Following Trauma or Unusual Effort. Ann. Int. Med. 40:327–339, 1954.
19. Moritz, Alan R.: Trauma, Stress and Coronary Thrombosis. J. A. M. A. 156:1306–1309, 1954.
20. Thomas, Geo. W.: Massive Contusion of the Myocardium Following Cardiac Massage. Am. J. Surg. 87:629–631, 1954.
21. Malamud, N., and Zhentlin, A.: Fatal Complications During Electroshock Therapy: Case Report. J. Nerv. & Ment. Dis. 117:458–464, 1953.
22. Strassman, Geo.: Traumatic Rupture of Aorta. Am. Heart J. 33:508–515, 1947.
23. Teare, Donald: Post-mortem Examinations on Air Crash Victims. Brit. Med. J. 2:707–708, 1951.

1005 East Blaine Street
Seattle 2, Washington

Comparatively Rare Mechanism of Death in Asphyxia by Carbon Monoxide

P. Moureau, M.D., Liege, Belgium*

It is well known that the complications of the central nervous system, when they are marked either by diffuse congestion with petechial perivascular hemorrhages, by thromboses, by softenings, or even by cerebellar edema, are among some of the elements of death by acute asphyxia with carbon monoxide (1–6).

However, quite often these complications in the central nervous system play a small part when death occurs in a toxic environment. As a contrast they play a very important part either in the primo-secondary death the first or second day after the event, or in the neuro-psychiatric or nervous complications dependent upon the injury to the central nervous system.

The mechanism of death of the individual whose history we are going to relate is sufficiently rare, it appeared to us, to demand our attention because it seems to be related to a pathological alteration occurring previously in the central nervous system. We had not found in the literature any similar observation, although Ponsold (7) mentions the possibility of such a death in cases of various intoxications.

Factual Account: During the winter of 1954–1955 we had been called to ascertain the death of a young girl of 14 who had succumbed in a room in which her grandfather, age 63, was also lying in a more or less comatose state, and whose condition necessitated his transfer to a hospital. On the other

* Professor of Legal Medicine at the University of Liege, Belgium.

hand, the grandmother had been found in a semi-conscious state in the kitchen of the first floor, beneath the bedroom where the above-mentioned victims had been discovered.

The origin of the trouble of these persons was the break of a gas pipe in the yard adjacent to the building. It was by filtering under the main door of the house that the gas had penetrated into the building. Asphyxia due to carbon monoxide was evident without a doubt. Indeed, the concentration of carboxyhemoglobin in the blood of both grandparents revealed for the grandfather a concentration of 43%, and for the grandmother 37%. It was quite surprising, however, to find that the young girl, quite developed for her age, measuring 1.65 meters (5′ 7″) in height, had succumbed in an environment which had not caused the death of two elderly people. But anatomopathological lesions were to give the explanation for this death.

Autopsy: Post-mortem lividity was red. The muscles presented vivid red color. The blood, in thin layer, was cherry red. The concentration of carboxyhemoglobin in the blood, with Nicloux method, revealed only 45.2% carboxyhemoglobin.

The macroscopic examination of the viscera revealed the following; the myocardium and the cardiac valves were normal. The lower lobes of both lungs were of rather firm consistency. The bronchi were filled with an abundant, foamy, salmon-colored liquid. On sectioning the lungs the parenchyma appeared clear with alternating dark red areas. On pressure, abundant edematous fluid could be expressed. Liver, spleen, kidney, uterus and ovaries, the thyroid and adrenal glands were apparently normal. The gastric mucosa was the site of relatively heavy hemorrhagic spotting. In the pharyngeal area the tonsils were enlarged and cryptic, the left one contained pus.

As soon as the cranial vault was opened and the dura mater was incised, the brain herniated itself. It was dry and definitely under tension. The convolutions were quite flattened. At the level of the cerebellum there was a marked protrusion of the cerebellar "tonsils" which had to be extracted from the foramen magnum. These "tonsils" were shaped into a well-marked cone, as seen in Figures 1 and 2.

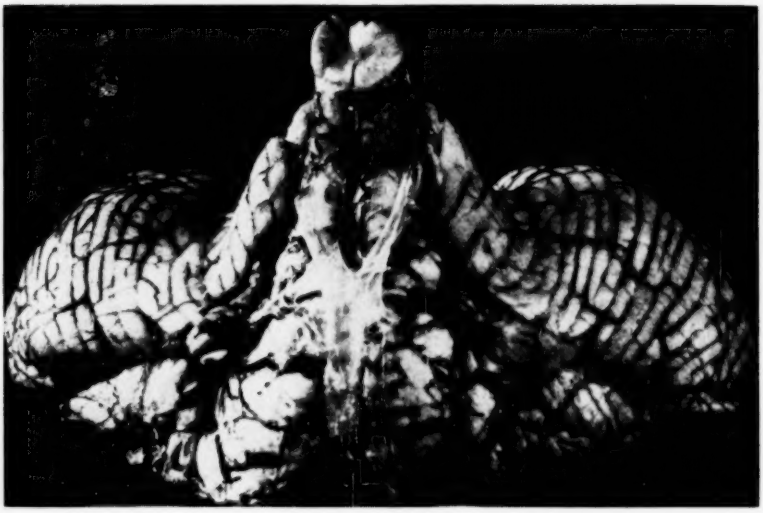


Fig. 1—"Pressure-cone" as seen from the inferior aspects of the cerebellum. Magnification—1.7.

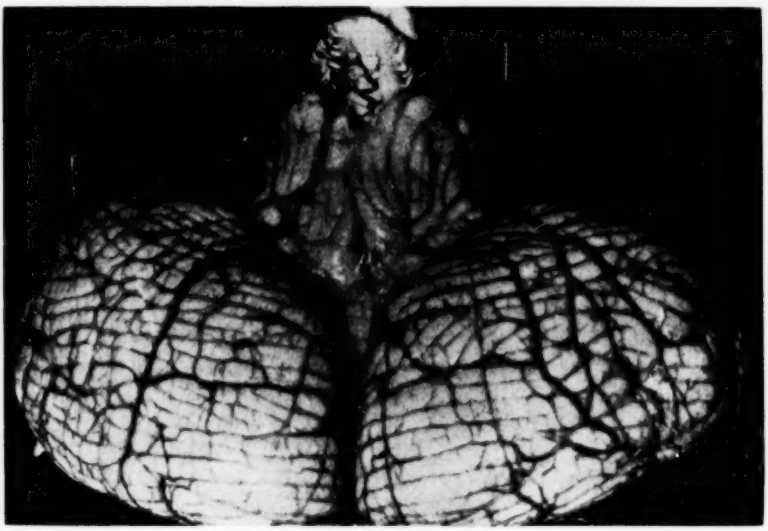


Fig. 2—"Pressure-cone" as seen from the superior aspects of the cerebellum. Magnification—1.7.

Sections of the brain, of the cerebellum and of the protuberance demonstrated congestion without hemorrhages.

Histologic Examinations: These were quite surprising. Besides the cerebellar edema, quite visible around the blood vessels under the form of dissociation of neuroglia fibers in the white matter (Figure 3) various organs presented other lesions. In the myocardium one could see signs of degeneration of myocardial fibers surrounded by bundles of fibrous tissues (Figure 4). In the lungs, besides chronic inflammatory lymphocytic infiltrations around some smaller bronchi,

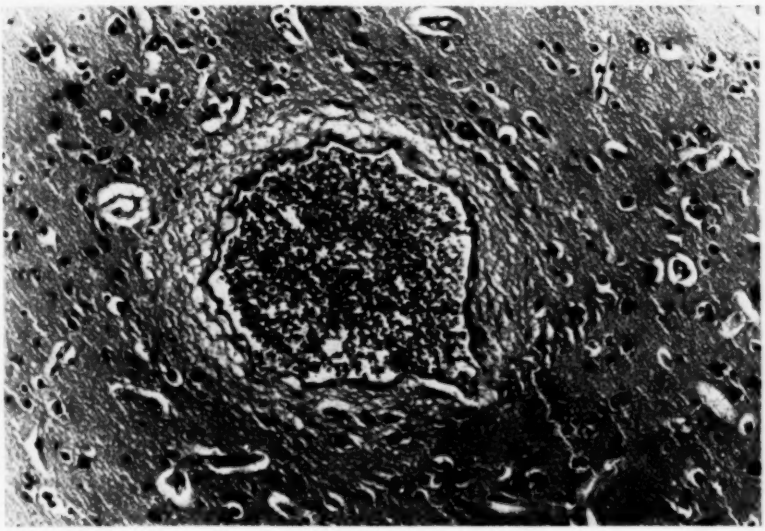


Fig. 3—Microphotograph: Perivascular cerebral edema—stain H. and E. Magnification—320.

occasional granulomatous lesions containing lymphocytes, epithelioid cells, and an occasional giant cell were present. In the liver, besides acute dilatation of the sinusoidals, one noted numerous granulomatous lesions whose center was completely necrotic and whose periphery was made up of epithelioid cells with occasional giant cells (Figure 5). In the kidneys we observed a few foci of fibrinoid necrosis in the glomerular tufts. In the spleen we observed hyalinization

and fibrinoid necrosis. Finally, the adrenals exhibited large zones of lipoid degeneration.

Bacteriologic studies of the granulomata in the liver and lungs failed to reveal bacteria and acid fast organisms.

Discussion: These observations enabled us to understand why this fourteen-year-old girl, apparently in good health, had succumbed to a carbon-monoxide asphyxia which had not caused the death of her grandparents. Indeed, in spite of her

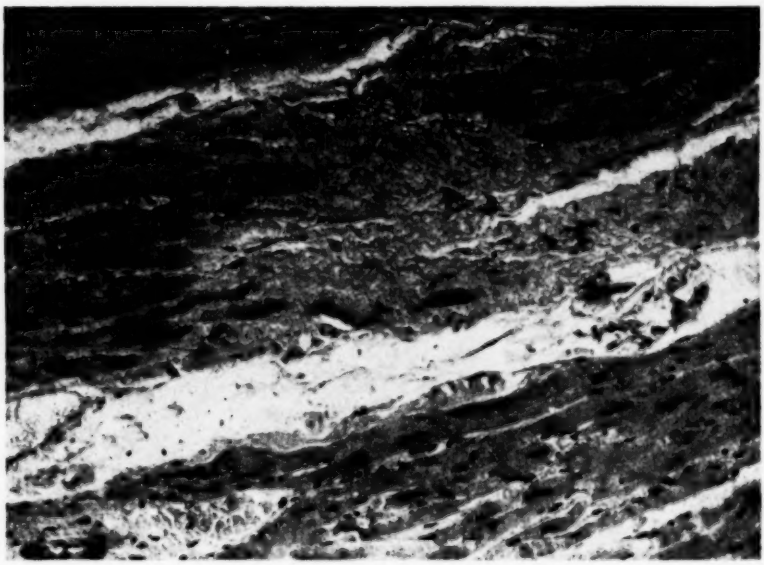


Fig. 4—Microphotograph: Fibrillary sclerosis of the myocardium—stain H. and E. Magnification—640.

healthy appearance, this young girl had contracted, without any one's notice, a disease of granulomatous and allergic nature which involved principally the lungs and liver, and had caused very limited sclerotic areas in the myocardium, or fibrinoid necrosis in the splenic arteries and renal glomeruli. We believe that this young girl must have contracted a rheumatoid-type of infection, without clinical signs, which would have given her family a warning.

Thus, carbon-monoxide asphyxia had attacked an organism whose cardiovascular function was deficient. We interpret this on the basis that the same quantity of carbon monoxide to which her grandparents were exposed, affected the young girl faster than her grandparents, because of severe circulatory impairments which provoked cerebellar edema and caused, by their severity, the herniation of cerebellar "tonsils," herniation which constituted the terminal event of the death of the young girl.

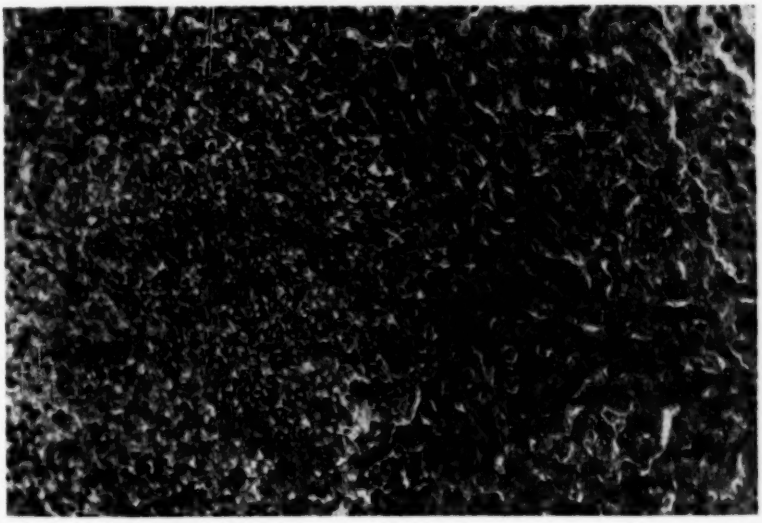


Fig. 5—Microphotograph: Granulomatous lesion in the liver—stain H. and E. Magnification—320.

Conclusions: The death of a fourteen-year-old girl asphyxiated with carbon monoxide, although her blood contained but 45.2% carboxyhemoglobin, is explained by the presence in the body of the victim of an infection of a granulomatous and allergic nature, probably rheumatoid, which caused an early cardiovascular failure with cerebellar edema and terminal herniation of cerebellar "tonsils."

Translated from the French by
Jean-Louis Riehl, M.D.

REFERENCES

1. Mueller, Berthold: Gerichliche Medizin, 1953, Springer-Verlag, Berlin-Göttingen-Heidelberg.
2. Strassmann, G.: Lehrbuch der gerichtlichen Medizin, 1931, Zweite Auflage Ferdinand Enke, Verlag, Stuttgart.
3. Smith, Sidney: Forensic Medicine, 1945, 8th Edition. J. and A. Churchill Ltd., London.
4. Simonin, C.: Médecine légale judiciare, 1947, 2é. édition. Maloine, Paris.
5. Gradwohl, R. B. H.: Legal Medicine, 1954. The C. V. Mosby Company, St. Louis, Missouri.
6. Gonzales, Vance, Helpern, and Umberger: Legal Medicine, Pathology and Toxicology, 1954, 2nd Edition. Appleton-Century-Crofts, Inc., New York.
7. Ponsold, A.: Lehrbuch der Gerichtlichen Medizin, 2te. Anflage, 1957, Georg Thieme Verlag, Stuttgart.

Professor of Legal Medicine
University of Liege
1 Rue des Bonnes Villes
Liege, Belgium

The Importance of the Time Interval Factor in the Relationship of Trauma to Tumor

Alfred Angrist, M.D., Bronx, N. Y.*

The primary purpose of this presentation is to outline the limitations of the logic which generally operates in the legal acceptance of trauma as a causal or aggravating factor in tumor formation, to stress the significance of the time relationship between trauma and tumor, and to illustrate the advantage of a graphic representation of this relationship in the evaluation of specific instances. The second purpose is to suggest a means of impartial evaluation of evidence to attain a better measure of uniformity and justice in legal adjudication.

In court procedure the legal fiction of death is accepted although no proof is presented beyond the presumption of disappearance of an individual. Similarly, the court upholds the argument that a single trauma may initiate or aggravate a tumor, when circumstantial evidence points to such a relationship. Much of the evidence of causality acceptable in court is frankly empirical, not subject to any scientific verification. But as long as the mechanism of tumor genesis is not known, a causal relationship often cannot be declared impossible.

Little direct experimental evidence favors a single trauma causing tumor. Richardson (1) has shown that hepatomas appeared more frequently in rats fed "butter-yellow" if needle punctures of the liver were also done, with some tumors at the site of scars. The complexities of this problem are attested by the fact that upon repeating this experiment in

* Albert Einstein College of Medicine, Bronx, New York.

another laboratory, results were different. Also, stomach tumors followed acetylaminofluorene in rats with the irritation of 95% alcohol (2).

While in criminal cases a lenient interpretation of evidence is desirable so that no individual suffer penalty unjustly, it is reasonable to expect in civil cases some substantial evidence, because it is circumstantial, relating to causality or aggravation of tumor.

Such requirements have been set forth by Segond (3) as follows:

1. Previous integrity of the part.
2. Authenticity and adequacy of the trauma.
3. Correspondence of trauma site to that of the tumor.
4. Positive proof of tumor and histological demonstration of its origin from the traumatized tissue.
5. Existence of a *reasonable time interval.*

In this paper we are mainly concerned with this time interval factor. It is highly significant in establishing, for legal purposes, an actual connection between trauma and tumor. Knowledge of time relationship is difficult to obtain, and evaluation of the evidence on this score frequently demands most discriminating judgment. Some cases with which the author has had direct contact may illustrate the possibilities of the application of the temporal relationship between trauma and tumor.

Case 1. A middle-aged man injured his heel while carrying a three-hundred-pound case, when his foot slipped off the step and struck the ground. Although suffering pain, he did not remove his shoe at the time. The foot became numb immediately and continued to pain him. Four days later, he examined the foot and saw in the region at the base of the fourth metatarsal a tender swollen area from which he expressed pus. According to the patient, this lesion occurred in the area where a corn several years earlier had been cauterized and had healed perfectly.

Six months later, a papillomatous mass of granulation tissue was found in the area of the metatarsal, and some pus exuded. It was incised and then excised, and the diagnosis of a non-pigmented melanoma was made. An amputation followed. Seven months later, the patient had a small inguinal node removed, measuring 4.5 $\times$ 2 cm. This node, occurring thirteen months after the original injury, showed metastatic melanoma. He continued symptomatic and died within the year of generalized disease.

It is our opinion that the injury merely called attention to an infection of a tumor already existing some distance from the site of the trauma. There is no evidence to indicate that the single injury caused the melanoma or aggravated its growth locally, particularly when the multiple trauma of weight-bearing during walking are considered. If activation of the tumor is to be considered at all, the infection there at the time of the injury causing sensitivity and pain four days later, should receive major consideration.

Graphic representation is helpful in delineating the relationship in time between trauma and tumor. Diagram 1 shows the growth of a tumor (in cu. cm.) plotted against time (in months). While for certain analytical purposes, as judging prognosis, a logarithmic plot is more useful (see Collins et al.) (4), the arithmetical plot which we employ corresponds more directly to common experience and is more readily grasped. Although far from established, we conceive tumor growth, as a first approximation, to result from geometric division of tumor cells—from 1 to 2, to 4, 8, 16, 32, etc.

In graphic analysis the *area* in a flat plane through the center of the tumor, as for example in an x-ray projection, is more readily expressed quantitatively than other features of tumors which may reflect the growth rate, such as anaplasia or incidence of mitosis. For graphic representation of increments of area, the arithmetical graph or the straight line relation of the growth curve on semilog paper seems more appropriate than a graph based on the log of the cube root used by Collins et al., which may be applied to increments of *volume* of the tumor.

In Diagram 1 it can be seen that the appearance of measurable tumor antedates the time of injury.

Another instance of the absence of relationship between trauma and tumor as represented in Diagram 1 is illustrated in the following case:

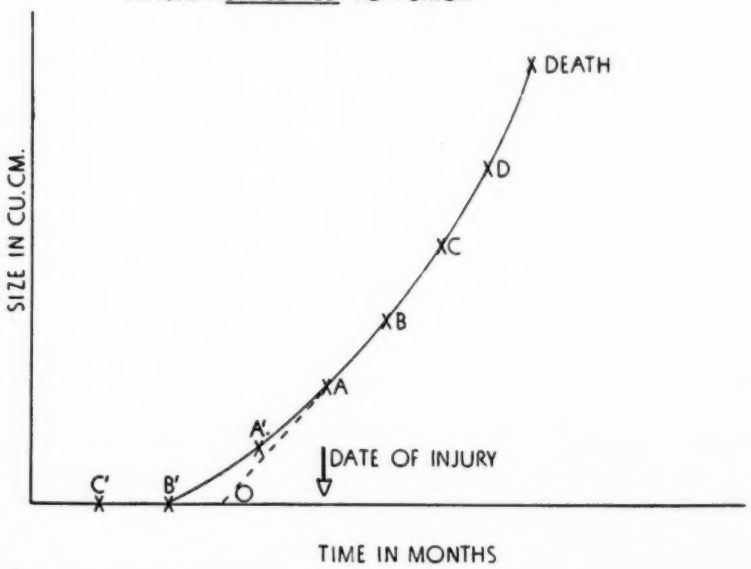
Case 2. While carrying a heavy tray, a waiter fell; he struck his knee as it gave way under him. He was treated locally, and after two months an x-ray was taken, showing a radiolucency 5 cm. in its smallest diameter. The patient refused operative interference and it increased in size only slightly for the next three months. A biopsy was then performed, and showed a giant cell tumor Grade II by Jaffe's classification.

The projection of the growth curve in this instance implied a pre-existing neoplasm; causal relation could not be entertained. No evidence existed to favor aggravation of the lesion, or to show increased growth or metastasis.

In our next cases we encounter instances where the trauma, although occurring after the tumor was presumably initiated,

DIAGRAM 1

TRAUMA UNRELATED TO TUMOR



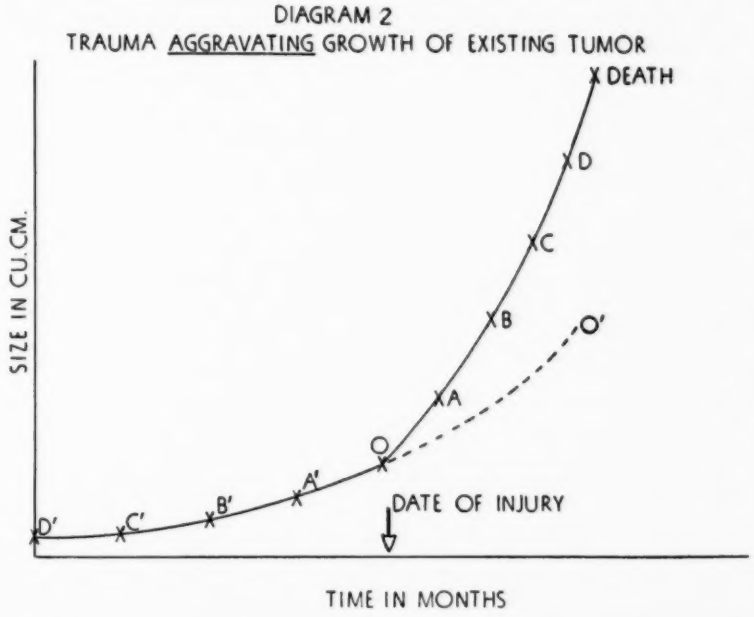
did influence it by speeding its growth. Such aggravation clearly warrants judicial compensation.

Case 3. A carpenter stepped on a nail which penetrated his shoe, causing puncture to a mole which he had always had on the bottom of his foot. The wound became infected and required wet dressings. The infection subsided, but the lesion remained crusted. Four months later, the patient appeared with large inguinal nodes. Biopsy showed metastatic melanoma, mainly non-pigmented. The original site, still showing a crust, was removed and showed malignant melanoma.

Case 4. A machinist got his thumb caught in meshing gears. The resulting crush injury was treated with splints and wet dressings. The site did not heal properly despite prolonged therapy with many medications. The biopsy showed a Hutchinson Whitlow (non-pig-

mented melanoma). The thumb had always been normal previously, with no apparent mole.

Diagram 2 shows the temporal relationship. Observations D′ through A′ establish the initial rate of tumor growth prior to the moment of injury, O. Observations A through D, extrapolated to O, indicate the increased speed of growth resulting from the injury.



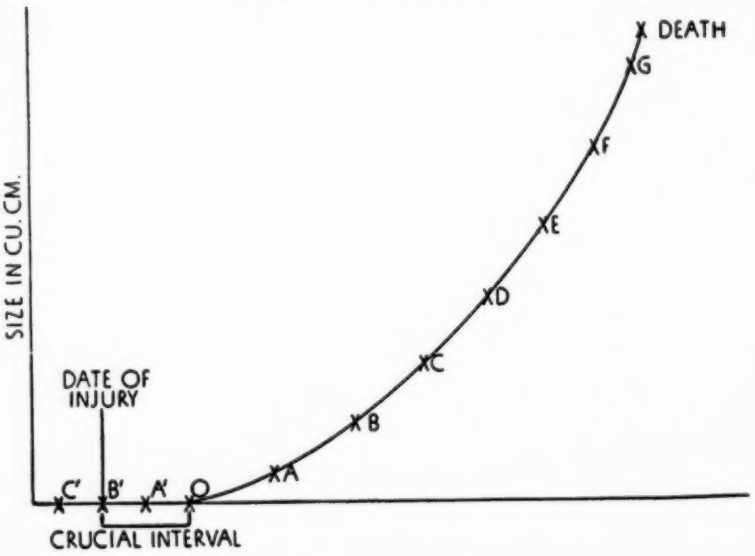
The temporal relationship showing causation by trauma of the tumor is represented in Diagram 3. Observations C′ -B′ and A′ indicate the integrity of the part and presumably the absence of malignant tumor. Observations A through G indicate the rate of active tumor growth. By extrapolation, the point O is obtained; this is the presumed moment of the tumor's origin. The interval between B′ and O constitutes the *crucial latent interval.*

In most courts of law, a causal relation between trauma and tumor should show a crucial latent period of no more than six months, but this is applied with considerable flexibility and

depends upon the established growth rate of the neoplasm and other factors.

DIAGRAM 3

TRAUMA POSSIBLY RELATED TO TUMOR



The crucial latent interval can vary with different tumors and with the same type of tumor. The cause of this variation is unknown. The nature of the injury apparently plays little or no part. A slight trauma is too often acceptable. An authentic and adequate trauma is usually sought. How adequate must a trauma be? Evidence of a visible contusion is usually required; this is equivalent to requiring that some blood vessels rupture. There is no theoretical basis for this demand, but we are confronted with an empirical and arbitrary compromise.

Causal relationship between trauma and tumor is illustrated in the following case:

Case 5. A twenty-seven-year old male was struck by the handle of a hydraulic press just above the knee, causing a bruise and consid-

erable pain, and requiring emergency treatment. An x-ray was not taken. He improved with diathermy and massage, but the pain persisted. Six weeks after the injury, an x-ray was taken, suggesting a traumatic periostitis on the basis of localized thickening of the periosteum corresponding to the site of injury. No bone destruction was present. Local therapy continued. After ten weeks another x-ray showed a minute questionable radiolucency in the cortex, corresponding to the site of injury. Four months after the injury a rarefied shadow 2 cm. in diameter was seen. This progressed to the size of 4 to 5 cm. in six months. A biopsy at that time established the diagnosis of osteolytic osteogenic sarcoma. The amputated limb confirmed the nature of the tumor and its size. This patient subsequently developed metastases to the lungs and two years after the injury he died.

Extrapolation from the plotted growth rate confirms the integrity of the bone in the initial x-ray. It strengthens the possibility of causal relationship.

An acute form of malignancy in which trauma seemed to play a part is shown in this last example.

Case 6. A middle-aged male insisted that his lip was always well and unblemished. He struck a match and the flaming head became attached and imbedded in the muco-cutaneous junction of the lower lip. It seared the flesh, which was charred, and part of the head of the match was imbedded in the freshly burned area. Local treatment was applied. The wound was a disturbing one and failed to heal. After three weeks, some induration was still present, although inflammation was not apparent. After six weeks, the entire zone was excised. A typical, moderately cellular squamous cell carcinoma was found.

It may be well to make some general observations concerning the graphic representation of tumor growth in relation to time.

Our Diagrams 1, 2 and 3 represent ideal situations, which are rarely, if ever, attained in practice. Measurements of tumor size may be few in number, particularly before the time of injury and shortly thereafter. The fewer the observations the less certain is the shape of the growth curve. Furthermore, tumor size is not an absolutely valid measure of rate of growth. For example, inflammatory and necrotic changes may greatly influence the apparent size of the tumor. In addition, growth may occur in cyclic spurts; in general, however, such spurts would not alter markedly the over-all ex-

ponential nature of the growth curve. Instead of the assumed origin, if the tumor were multicentric, then the actual growth curve might diverge appreciably from those shown. The extent of the divergence would depend upon the time interval between the initiation of tumor cells at different foci, and the relative rates of cell division in these foci.

Despite these uncertainties, the graphic method is helpful in the determination of the crucial latent time interval. Simple extrapolation from the growth curve of Diagram 3 gives the theoretical time of tumor appearance (point O), and the interval between time of injury and O is the crucial time interval. It is worth emphasizing the desirability of extrapolating by a linear line from the *steepest* portion of the curve (dotted lines in Diagram 2). This makes the point O as far to the right in the graph as possible. This is to the patient's advantage since, as in Diagram 2, it tends to bring the time of origin of the tumor into the most favorable relation to the date of injury, and as in Diagram 3, it increases the apparent interval between the time of injury and the appearance of tumor. Giving such advantage to the patient is warranted in the absence of precise knowledge of the time of the tumor's appearance.

At the moment, we can say little regarding the nature of the crucial interval. It is unlikely that a trauma would be so selective locally that it would irritate a single cell and in turn affect its biochemical mechanism of reproduction. In the initiation of the tumor process, it seems that some alteration in the function of reproduction, as it applies to the phenomenon of repair and regeneration secondary to the injury, is at issue. Some time interval is required for such repair and regenerative proliferation of issues. In reality, much of the crucial interval may be expended in development of the precancerous rather than malignant state, corresponding to the latent interval in experimental carcinogenesis—the time between the application of the carcinogen and the appearance of the tumor.

It is evident that the crucial interval will vary with the type of tumor. Tumors differ in their rates of growth, rate of expansion, extension and metastasis in their tissue sites, changes in growth rate, extent of necrosis, confining tissue

planes and extent of multicentricity of cell origin, and other circumstances now unknown.

Appropriate temporal relationship is not proof of causal relation; it only indicates such a possibility. All of the other Segond requirements must be met in the analysis of any single case. If any one of the Segond requirements is lacking, the time factor is reduced to the error inherent in post hoc propter hoc and becomes mere coincidence.

The following instance indicates how far afield too great emphasis upon the time association only can lead us.

Case 7. In a recent compensation case, a man was struck a severe blow in his groin, and felt acute pain. Within a few days he had a swelling in this region. This was finally incised and then excised. The histology showed the specific pathology of lymphogranuloma inguinale. This is a venereal disease acquired by coitus. Despite this fact, this man was granted full compensation on the theory that the injury was the cause of the swelling, the operation, and the resulting incapacity.

In this instance, the tumorous swelling was due to an infection which runs this characteristic clinical course with such enlargement of the lymph nodes entirely independent of any trauma. The legal decision is really equivalent to the acceptance of the spontaneous generation of a lymphogranuloma virus by a single trauma.

It is our conviction that graphic analysis of time data will be found of value in other diseases as well as cancer, and with other causes as well as trauma. With discretion, it can find wide application to other diseases associated with physical or chemical injury and infection.

Graphic illustration may have a secondary, yet important value. It may help dramatize the lack of information for experts called upon for testimony in court. Nothing is so discouraging as the glib expressions of opinion by those unaware of the complexities of tumor genesis, particularly since such glib opinions are more assertive and superficially more impressive than the qualified statements and hedging opinions of pathologists who do not wish to commit themselves unequivocally in the absence of sufficient evidence.

This leads to a problem of utmost importance in the adjudication of claims. The need for a qualified Board of Re-

view (5) or Impartial Panel of Experts is urgent to control expert medical testimony in all litigation, as well as in cases involving trauma as the cause of cancer. This Board should consist of the most qualified pathologists of the community devoted to the correction of inadequacy and abuse in medical testimony. Ordinarily, testimony should be limited to the question of impossibility, possibility, or probability of causation of tumor by trauma. A uniformity of definition, interpretation and evaluation is necessary, in fairness to the patient who is not prepared to bargain for opinions. If the awkward instrument of the hypothetical question is to be a useful means of obtaining delimited opinion data, it should be submitted to a Board that is impartial.

In civil actions, causal relationship of trauma to tumor is not presumed, and the burden of proof which is now placed upon the claimant could be assumed by such a Board in selected cases, such as compensation claims. The outcome of such analytical opinions may provide partial compensation when some requisites for proof of causal relationship are lacking.

Recently an attempt to obtain the medical facts and expert opinion has been made through the efforts of Judge David Pick, Presiding Justice, and Judge Bernard Botein, Associate Justice of the Supreme Court of New York State, Appellate Division, First Department (6). Prompted by a serious backlog of negligence cases, a panel of experts was established through the cooperation of the Association of the Bar of New York City, the New York County Lawyers Association, the Medical Society of the County of New York and the New York Academy of Medicine. This panel obtains impartial testimony for the guidance of the Justice at pre-trial hearings, or at the time of the trial. This impartial panel serves its purpose well. There is need, however, for their services to be extended to include consideration of compensation cases and criminal actions, and the wide range of cases requiring accurate and scientific facts in medical testimony.

Summary

The interval of time between a trauma and the observed appearance of a tumor is most helpful in determining the

presumption or legal fiction of causation or aggravation of tumor by trauma.

The theoretical basis for this crucial time interval is discussed.

The significance of the graphic method of analysis of the crucial time interval is indicated and is applied to specific instances. The possible expansion of its use is noted for pathological conditions other than tumor, as related to causative etiology other than trauma, as chemical injury or infections.

The distinct limitations of the graphic method in its practical application from the standpoint of scientific proof are stressed.

The creation of a Medicolegal Board of Review and Opinion or Impartial Panel of Experts is recommended. The advantages of such a body to further justice and advance unbiased opinion and scientific medicolegal knowledge and procedure are outlined and borne out by recent experience in New York County.

REFERENCES

1. Richardson, Howard L.: Effect of Trauma on the Induction of Liver Cancer in Rats Fed the Azo Dye 3′-Methyl-4 Dimethylaminoazobenzene. Proc. Amer. Assoc. for Cancer Res. 2, No. 1, p. 41, April 1955.
2. Richardson, Howard L: Induction of Adenocarcinoma of the Glandular Stomach in Rats by Alcohol Gastric Lavage and Feeding Acetylaminofluorene. Proc. Amer. Assoc. for Cancer Res. 2, No. 2, p. 141–142, April 1956.
3. Segond, Paul: Le cancer et le accidents du travail. Assoc. Franc de Chir. 20:745, 1907.
4. Collins, Vincent P., Loeffler, R. K., and Tivey, H.: Observations on Growth Rates of Human Tumors, Amer. J. of Roentgen, Radium Therapy & Nuclear Med. 76:988–1000, 1956.
5. Angrist, Alfred: Hospital Service of Certification of Death, Hospitals, 15 (Nov.): 100–116, 1941.
6. Impartial Medical Testimony—Report of Special Committee of the Bar Association of City of New York on Medical Expert Testimony. Macmillan, 1956.

Department of Pathology
Albert Einstein College of Medicine
Bronx 61, New York City

Chromatographic Methods of Analysis Applied to Forensic Problems*

*Arthur J. McBay, Ph.D.,** Boston, Mass.*

Chromatography, which was rediscovered in the last decade after being neglected for about a century, has become an important tool for the toxicologists and chemists in the field of forensic science.

In recent years gas chromatography has become the method of choice for the separation of liquids. Recently Brenner (1) discussed applications of interest to the forensic chemist. These were demonstrated with the analysis of alcohol in an aqueous distillate of blood, and the identification of alcohol in exhaled air. Further applications, which include the identification of incendiary materials, and sewer gas vs. natural or manufactured gas, and extracted volatiles will be of particular value to the chemist who must identify these substances for fire investigators.

Paper chromatography has been the most useful of the divisions of chromatography, although occasionally columnar chromatography has been instrumental in the separation of materials of interest to the forensic scientist.

Numerous articles and many books and reviews have been written on chromatography. Although many of these articles are valuable to the toxicologist, only a few concern other

---

* Presented at the Ninth Annual Meeting of the American Academy of Forensic Sciences, March 2, 1957, Chicago, Illinois.

** Assistant in Legal Medicine, Harvard Medical School; Supervisor, Chemical Laboratory, Massachusetts Department of Public Safety, Boston, Massachusetts.

areas of interest to the forensic scientist. Recently both Lederer (2) and Curry (3) have reviewed the applications of paper chromatography to forensic science.

From practical experience and from a survey of these articles certain distinct advantages to the forensic scientist may be realized.

These include:

1. Small amount of sample.
2. Simple technique.
3. Equipment and materials available and inexpensive.
4. Separation of mixtures.
5. Comparisons possible.
6. Material easily recovered.
7. Non-destructive analysis.

Paper chromatography may be a means of showing dissimilarities between two or more samples when the materials on the paper have different Rf values under identical conditions. The fact that two substances occupy the same zone under identical conditions does not preclude the possibility that the substances are different. However, choice of extractive procedures, treatment with color-producing reagents or spectrophotometry of an eluate may certainly lead to the establishment of identity. Also, if identification is still not possible, the results will indicate to the analyst the course to be followed for the resolution of his problem.

Because of the variety of nitrogenous bases used in medicine any compact method of separating and identifying small amounts of these substances is exceedingly important to the toxicologist. The pioneers in this phase of paper chromatography were Munier and Macheboeuf (4). More recent reports concerning applications to the alkaloids have been made by Mannering and co-workers (5) and Curry and Powell (6). In addition to the alkaloids Belles and Siever (7) included the antihistamines, and Goldbaum and Kazyak (8) included other bases.

O'Dea and Liss (9) documented a case of poisoning with Methapyrilene (Dormin), which was satisfactorily established with the aid of paper chromatography. Chlorpromazine (Thorazine) and its metabolite have been separated by Salz-

man and Brodie (10). The metabolite, chlorpromazine sulfoxide, has been found during the analysis of urine for alkaloids. The ultraviolet spectrum is characteristic and interference by other bases may be overcome by separation using paper chromatography.

Sheppard and co-workers (11) were able to separate Glutethimide (Doriden) from its metabolite by paper chromatography, after obtaining selectivity in their method of determination by using columnar chromatography prior to the paper chromatography. Katsas and McBay (12) have used their method in the investigation of fatalities following Doriden ingestion.

The most important acids encountered in forensic chemistry are the barbiturates. It is not usually necessary to use chromatography to separate the barbiturates from other acidic materials since this can be accomplished by other means. With the advent of the use of mixtures of barbiturates in therapy it has become important to separate the less toxic phenobarbital from the more toxic rapid-acting barbiturates. The establishment of the presence or absence of phenobarbital in blood extracts where the level of 1 to 3 mgm. % or greater can often be vital to the proper interpretation of the finding. Such a level of phenobarbital may be produced by continual therapeutic doses (13) but the same level of rapid-acting barbiturate may be sufficient cause for death.

Algeri and Walker (14) have applied paper chromatography to the separation of barbiturates and have given color-producing reagents which may be useful. Wright (15) favors the use of buffered paper for this separation and claims that his method will separate the rapid-acting barbiturates, pentobarbital, secobarbital and amobarbital. McBay and Algeri (16) have detected barbiturates on paper chromatograms by means of ultraviolet densitometry. The advantage of densitometry is that the strips are available for color tests and for elution and further determinations. Algeri and McBay (17, 18), Curry (19), and Titus and Weiss (20) have used paper chromatography in establishing the presence of urinary metabolites of the barbiturates. Titus and Weiss (20) used radioactive indicators and prepared radioautograms to obtain the R_f values.

Curry (21) has found paper omatography useful in separating and appraising materials which interfere with ultraviolet spectrophotometry of the barbiturates. Algeri (22) has found the same applies to interfering substances found in fixed and putrefied tissue.

Reports on the paper chromatography of inks have been written by Somerford (23), Brackett, and Bradford (24), Brown and Kirk (25), Martin (26, 27), and Coldwell (28). In summary, inks may be compared, particularly when writings have been made at different times or with certain different types of inks, but rarely may an ink be identified.

Brown and Kirk (29) have had some success in applying paper chromatography to the analysis of typewriter ribbons. Horizontal circular chromatography may be used when pieces of the original ribbon are available.

The comparison of roofing asphalts by paper chromatography has been suggested as being useful in criminal investigation (30).

Coldwell (28) states that he has used paper chromatography for the comparison of chips of varnish, and for the comparison of dyestuffs from the hood of an auto and from clothing. Curry (3) mentions the comparison of sugars in stolen candies, oils and greases from stolen bicycles, and oils and greases from automobiles involved in accidents.

REFERENCES

1. Brenner, N.: The Application of Vapor Fractometry to Criminal Investigation. Perkin-Elmer Instrument News, 8:3, 1956.
2. Lederer, M.: Paper Chromatography in Forensic Science. Research (London), 8:357–360, 1955.
3. Curry, A. S.: The Application of Paper Chromatography to Forensic Chemistry, J. Criminal Law, Criminol. & Police Sci. 44:787–793, 1954.
4. Munier, R., and Macheboeuf, M.: Microchromatographie de Partage des Alcoloides et De Diverses Bases Azotees Biologiques, I. Bull. Soc. chim.bio. 31:1144–1162, 1949.

II.	Ibid.	32:192–212, 1950.
III.	Ibid.	33:846–856, 1951.
IV.	Ibid.	33:857–861, 1951.
V.	Ibid.	33:862–867, 1951.

5. Mannering, J. J., Dixon, A. C., Carroll, N. V., and Cope, O. B.: Paper Chromatography Applied to the Detection of Opium Alkaloids in Urine and Tissues. J. Lab. & Clin. Med. 44:292–300, 1954.

6. Curry, A. S., and Powell, H.: Paper Chromatographic Examination of the Alkaloid Extract in Toxicology. Nature, London, 173:1143–1144, 1954.
7. Belles, Q. C., and Siever, H. W.: Descending Chromatographic Behavior and Differentiation of Some Antihistaminics and Alkaloids. J. Lab. & Clin. Med. 46:628–640, 1955.
8. Goldbaum, L. R., and Kazyak, L.: Identification of Alkaloids and Other Basic Drugs by Paper Partition Chromatography. Anal. Chem. 28:1289–1290, 1956.
9. O'Dea, A. E., and Liss, M.: Suicidal Poisoning by Methapyrilene Hydrochloride with Documentation by Paper Chromatography. New England J. Med., 249:566–567, 1953.
10. Salzman, N. P., and Brodie, B. B.: Physiological Disposition and Fate of Chlorpromazine and a Method for its Estimation in Biological Material. J. Pharmacol. & Exper. Therap. 118:46–54, 1956.
11. Sheppard, H., D'Asaro, B. S., and Plummer, A. J.: The Detection of Glutethimide (Doriden) and a Metabolite in Dog Urine. J. Am. Pharm. A. (Scient. Ed.) 45:681–684, 1956.
12. McBay, A. J., and Katsas, G. G.: Glutethimide (Doriden) Poisoning. New England J. Med. 1957.
13. Butler, T. C., Newhoffer, C., and Woddell, W. J.: Phenobarbital: Studies of Elimination, Accumulation, Tolerance and Dosage Schedules. J. Pharmacol. & Exper. Therap. 111:425–435, 1954.
14. Algeri, E. J., and Walker, J. T.: Paper Chromatography for Identification of the Common Barbiturates. Am. J. Clin. Path. 22:37–40, 1952.
15. Wright, J. T.: A Rapid Method of Identifying Particular Barbiturate Derivatives in Small Samples of Blood by Paper Chromatography. J. Clin. Path. 7:61–65, 1954.
16. McBay, A. J., and Algeri, E. J.: Application of Densitometry to Paper Chromatography of Barbiturates. Am. J. Clin. Path. 24:1139–1143, 1954.
17. Algeri, E. J., and McBay, A. J.: Paper Chromatography of Urinary Metabolites of Pentobarbital. Am. J. Clin. Path. 23:654–660, 1953.
18. Algeri, E. J., and McBay, A. J.: Metabolite of Phenobarbital in Human Urine. Science, 123:183–184, 1956.
19. Curry, A. S.: A Note on a Urinary Metabolite of Phenobarbital. J. Pharm. & Pharmacol. 7:1072–1073, 1955.
20. Titus, E., and Weiss, H.: The Use of Biologically Prepared Radioactive Indicators in Metabolite Studies: Metabolism of Pentobarbital. J. Biol. Chem. 214:807–820, 1955.
21. Curry, A. S.: Interference to the Ultraviolet Spectrophotometry of Barbiturates. Nature, London, 176:877–878, 1955.
22. Algeri, E. J.: The Determination of Barbiturate After Putrefaction. Jour. Forensic Sciences, 1957.
23. Somerford, A. W.: Comparison of Writing Inks by Paper Chromatography. J. Criminal Law, Criminol. & Police Sci. 43:124–127, 1952.

24. Brackett, J. W., and Bradford, L. W.: Comparison of Ink Writing on Documents by Means of Paper Chromatography, Ibid. 43:530–539, 1952.
25. Brown, C. L., and Kirk, P. L.: Horizontal Paper Chromatography in the Identification of Ball Point Inks. Ibid. 45:334–339, 1954.
26. Martin, E.: Chromatographic Microanalysis of Dried Ink, International Criminal Police Review, 81:232–238, 1954.
27. Martin, E.: Further Developments in the Chromatographic Analysis of Dried Ink. Ibid. 91:257–258, 1955.
28. Coldwell, B. B.: The Comparison of Inks and Writings by Paper Chromatography. Analyst, 80:68–72, 1955.
29. Brown, C. L., and Kirk, P. L.: Identification of Typewriter Ribbons. J. Criminal Law, Criminol. & Police Sci. 46:882–885, 1956.
30. Anonymous: Chromatographic Analysis, Technical News Bulletin, National Bureau of Standards, 39(4), 1955.

25 Shattuck Street
Boston 15, Massachusetts

Modification of Wiener and Wexler's Table

Exclusion of Paternity in Suits for Derivative Citizenship

*Perry Morgan, Ph.D., and V. Lyle von Riesen, Ph.D.**

Sussman (1) pointed out that the medicolegal application of blood grouping tests has been extended to include the problem of derivative citizenship in the United States. Blood testing procedures were introduced by the Immigration and Naturalization Service and the State Department following an enormous increase in applications from Chinese in the past three years for derivative citizenship. Blood grouping tests were found to demonstrate the falsity of paternity claims in approximately 80 per cent of the applications made for derivative citizenship. The compact table for exclusion of parentage by Rh-Hr tests prepared by Wiener and Wexler (2) in modification of Boyd's (3) tabular presentation can be amended simply to indicate quickly exclusions when the child (or children) and only the alleged father are tested. Table 1 includes the addendum to Wiener and Wexler's table (2) necessary to include the phenotypes of children for whom paternity is excluded. The numbers in parentheses appearing in Table 1 indicate phenotypes that, if found for the child, exclude paternity. As an example, a male of phenotype Rh_0 (genotypes $R^\circ R^\circ$ and $R^\circ r$) cannot be the father of a child, of phenotype rh′rh′, rh_yrh', Rh_1Rh_1, or Rh_2Rh_1, in which the genes R° or r are absent.

In the tabular presentations of Boyd (3) and Wiener and Wexler (2) as well as Table 1, the assumption is made that the

* From the Department of Medical Microbiology, University of Kansas Medical School, Kansas City 12, Kansas.

tests had been performed with 4 antisera: anti-**Rh_0**, anti-**rh′**, anti-**rh″**, and anti-**hr′**. Wiener *et al.* (4) cited explanation and application of the table prepared by Wiener and Wexler.

Summary

The Wiener and Wexler's table for exclusion of parentage by the Rh-Hr tests was modified in order to include the exclusion of paternity when a child (or children) and only the alleged father are tested. Such a modification makes the table useful in the exclusion of paternity in suits for derivative citizenships.

REFERENCES

1. Sussman, L. N.: Application of Blood Grouping to Derivative Citizenship. J. Forensic Sciences, Vol. 1, No. 4, pp. 101–108, 1956.
2. Wiener, A. S. and Wexler, I. B.: Exclusion of Parentage by Rh-Hr Tests. J. Forensic Med., 3:67–71, 1956.
3. Boyd, W. C.: Compact Tabular Presentation of Mother-Child-Alleged Father Combinations Which Establish Non-Paternity in the Rh Blood Group System. Vox Sanguinis, 5:99–101, 1955.
4. Wiener, A. S., Owen, R. D., Stormont, C. and Wexler, I. B.: Medicolegal Applications of Blood Grouping Tests. J. A. M. A., 161:233–239, 1956 and J. Forensic Med., 3:98–114, 1956.

TABLE 1

EXCLUSION OF PARENTAGE BY Rh–Hr TYPES *

Putative Mother		Putative Father (Assigned number and phenotype)											
		1	2	3	4	5	6	7	8	9	10	11	12
Assigned Number	Phenotype	rh	rh'rh	rh'rh'	rh"	rh'rh"	rh_yrh'	Rh_0	Rh_1rh	Rh_1Rh_1	Rh_2	Rh_1Rh_2	Rh_ZRh_1
1	rh	2, **(3)**, 4, 5 **(6)**, 7, 8, **(9)**, 10, 11 **(12)**	**3**, 4, 5, **6**, 7, 8, **9**, 10, 11, **12**	(1), **3**, (4), 5, **6**, (7), 8, **9**, (10), 11, **12**	2, **(3)**, 5, **(6)**, 7, 8, **(9)**, 10, 11, **(12)**	**3, 6**, 7, 8, **9**, 10, 11, **12**	(1), **3**, (4), **6**, (7), 8, **9**, (10), 11, **12**	2, **(3)**, 4, 5, **(6)**, 8, **(9)**, 10, 11, **(12)**	**3**, 4, 5, **6, 9**, 10, 11, **12**	(1), **3**, (4), 5, **6**, (7), **9**, (10), 11, **12**	2, **(3)**, 5, **(6)**, 8, **(9)**, 11, **(12)**	**3, 6, 9, 12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**
2	rh'rh	(3), 4, 5, (6), 7, 8, (9), 10, 11, (12)	4, 5, 6, 7, 8, 9, 10, 11, 12	(1), (4), 5, 6, (7), 8, 9, (10), 11, 12	(3), (6), 7, 8, (9), 10, 11, (12)	7, 8, 9, 10, 11, 12	(1), (4), (7), 8, 9, (10), 11, 12	(3), 4, 5, (6), (9), 10, 11, (12)	4, 5, 6, 10, 11, 12	(1), (4), 5, 6, (7), (10), 11, 12	(3), (6), (9), (12)	None	(1), (4), (7), (10)
3	rh'rh'	1, (3), 4, 5, (6), 7, 8, (9), **10**, 11, (12)	**1**, 4, 5, 6, **7**, 8, 9, **10**, 11, 12	(1), 2, (4), 5, 6, (7), 8, 9, (10), 11, 12	1, (3), 4, (6), 7, 8, (9), **10**, 11, (12)	**1, 4, 7**, 8, 9, **10**, 11, 12	(1), 2, (4), 5, (7), 8, 9, (10), 11, 12	1, (3), 4, 5, (6), 7, (9), **10**, 11, (12)	**1**, 4, 5, 6, **7**, **10**, 11, 12	(1), 2, (4), 5, 6, (7), 8, (10), 11, 12	1, (3), 4, (6), 7, (9), **10**, (12)	**1, 4, 7, 10**	(1), 2, (4), 5, (7), 8, (10), 11
4	rh"	2, (3), 5, (6), 7, 8, (9), 10, 11, (12)	**3, 6**, 7, 8, **9**, 10, 11, **12**	(1), **3**, (4), **6**, (7), 8, **9**, (10), 11, **12**	2, (3), 5, (6), 7, 8, (9), 10, 11, (12)	**3, 6**, 7, 8, **9**, 10, 11, **12**	(1), **3**, (4), **6**, (7), 8, **9**, (10), 11, **12**	2, (3), 5, (6), 8, (9), 11, (12)	**3, 6, 9, 12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**	2, **3**, 5, (6), 8, (9), 11, (12)	**3, 6, 9, 12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**
5	rh'rh"	(3), (6), 7, 8, (9), 10, 11, (12)	7, 8, 9, 10, 11, 12	(1), (4), (7), 8, 9, (10), 11, 12	(3), (6), 7, 8, (9), 10, 11, (12)	7, 8, 9, 10, 11, 12	(1), (4), (7), 8, 9, (10), 11, 12	(1), (3), (6), (9)	None	(1), (4), (7), (10)	(3), (6), (9), (12)	None	(1), (4), (7), (10)
6	rh_yrh'	**1**, (3), **4**, (6), **7**, 8, (9), **10**, 11, **(12)**	**1, 4, 7**, 8, 9, **10**, 11, 12	**(1)**, 2, **(4)**, 5, **(7)**, 8, 9, **(10)**, 11, 12	**1**, (3), **4**, (6), **7**, 8, (9), **10**, 11, (12)	**1, 4, 7**, 8, 9, **10**, 11, 12	**(1)**, 2, **(4)**, 5, **(7)**, 8, 9, **(10)**, 11, 12	**1**, (3), **4**, (6), **7**, (9), **10**, (12)	**1, 4, 7, 10**	**(1)**, 2, **(4)**, 5, **(7)**, 8, **(10)**, 11	**1**, (3), **4**, (6), **7**, (9), **10**, (12)	**1, 4, 7, 10**	**(1)**, 2, **(4)**, 5, **(7)**, 8, **(10)**, 11

7	Rh_0	2, **(3)**, 4, 5, **(6)**, 8, **(9)**, 10, 11, **(12)**	**3**, 4, 5, **6**, **9**, 10, 11, **12**	(1), **3**, (4), 5, **6**, (7), **9**, (10), 11, **12**	2, **(3)**, 5, **(6)**, 8, **(9)**, 11, **(12)**	**3**, **6**, **9**, **12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**	2, **(3)**, 4, 5, **(6)**, 8, **(9)**, 10, 11, **(12)**	**3**, 4, 5, **6**, **9**, 10, 11, **12**	(1), **3**, (4), 5, **6**, (7), **9**, (10), 11, **12**	2, **(3)**, 5, **(6)**, 8, **(9)**, 11, **(12)**	**3**, **6**, **9**, **12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**
8	Rh_1rh	(3), 4, 5, (6), (9), 10, 11, (12)	4, 5, 6, 10, 11, 12	(1), (4), 5, 6, (7), (10), 11, 12	(3), (6), (9), (12)	None	(1), (4), (7), (10)	(3), 4, 5, (6), (9), 10, 11, (12)	4, 5, 6, 10, 11, 12	(1), (4), 5, 6, (7), (10), 11, 12	(3), (6), (9), (12)	None	(1), (4), (7), (10)
9	Rh_1Rh_1	**1**, (3), **4**, 5, (6), **7**, (9), **10**, 11, (12)	**1**, **4**, 5, 6, **7**, **10**, 11, 12	**(1)**, 2, (4), 5, 6, **(7)**, 8, **(10)**, 11, 12	**1**, (3), **4**, **(6)**, **7**, (9), **10**, (12)	**1**, **4**, **7**, **10**	**(1)**, 2, **(4)**, 5, **(7)**, 8, **(10)**, 11	**1**, (3), **4**, 5, **(6)**, **7**, (9), **10**, 11, (12)	**1**, **4**, 5, 6, **7**, **10**, 11, 12	**(1)**, 2, **(4)**, 5, 6, **(7)**, 8, **(10)**, 11, 12	**1**, **(3)**, **4**, **(6)**, **7**, **(9)**, **10**, **(12)**	**1**, **4**, **7**, **10**	**(1)**, 2, **(4)**, 5, **(7)**, 8 **(10)**, 11
10	Rh_2	2, **(3)**, 5, **(6)**, 8, **(9)**, 11, **(12)**	**3**, **6**, **9**, **12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**	2, **(3)**, 5, **(6)**, 8, **(9)**, 11, **(12)**	**3**, **6**, **9**, **12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**	2, **(3)**, 5, **(6)**, 8, **(9)**, 11, **(12)**	**3**, **6**, **9**, **12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**	2, **(3)**, 5, **(6)**, 8,**(9)**, 11, **(12)**	**3**, **6**, **9**, **12**	(1), **3**, (4), **6**, (7), **9**, (10), **12**
11	Rh_1Rh_2	(3), (6), (9), (12)	None	(1), (4), (7), (10)	(3), (6), (9), (12)	None	(1), (4), (7), (10)	(3), (6), (9), (12)	None	(1), (4), (7), (10)	(3), (6), (9), (12)	None	(1), (4), (7), (10)
12	Rh_zRh_1	**1**, (3), **4**, (6), **7**, (9), **10**, (12)	**1**, **4**, **7**, **10**	**(1)**, 2, (4), 5, **(7)**, 8, **(10)**, 11	**1**, (3), **4**, (6), **7**, (9), **10**, (12)	**1**, **4**, **7**, **10**	(1), 2, (4), 5, **(7)**, 8, **(10)**, 11	**1**, (3), **4**, (6), **7**, (9), **10**, (12)	**1**, **4**, **7**, **10**	**(1)**, (2), (4), 5, **(7)**, 8, **(10)**, 11	**1**, (3), **4**, (6), **7**, (9), **10**, (12)	**1**, **4**, **7**, **10**	**(1)**, 2, (4), 5, **(7)**, (8), **(10)**, 11

* To understand and use this chart quickly and easily, the phenotype names and assigned numbers should be used in conjunction with the table of Rh–Hr reactions (table 3 in ref. 4). 1. Determine the Rh-Hr phenotypes of the blood of the child (or children), the putative father and/or the putative mother using potent and specific anti-Rh_0, anti-**rh'**, anti-**rh"**, and anti-**hr'** serums, including appropriate controls. 2. Assign the corresponding phenotype symbol and number to each individual tested. 3. When both the mother and putative father are tested, find the assigned number of the putative mother (left hand column) and putative father (top row) and locate the point at which both intersect. The child or children are not possible from this mating if their assigned numbers appear in this area. 4. Phenotype numbers given in boldface represent children for whom maternity is excluded. 5. Phenotype numbers which are in parentheses represent children for whom paternity is excluded in situations when only the alleged father and child are tested.

Confessions of a Cross-Examiner*

Erle Stanley Gardner, Temecula, Calif.

I know that from time to time members of this academy have expressed some concern over cross-examination, particularly in regard to the question of compensation.

When I was practicing law I more or less specialized in cross-examining experts. At times I would be asked by other attorneys to sit in the case for the sole purpose of cross-examining the doctors. I thought you might be interested in hearing something from the other side of the fence—the viewpoint of the cross-examiner himself.

The expert witnesses who befuddled me were the ones who followed certain tactics. Fortunately there weren't too many of them, but these few experts followed a certain general plan of procedure. I was never able to find the answer to tactics of the type they used and I don't think there is any answer.

When a lawyer asks an expert about his compensation it is usually in a case being tried before a jury and the lawyer tries to be as unfair as possible. The question is almost never asked for the purpose of legitimate information, but is asked purely for the purpose of embarrassing the witness and of getting him on the defensive. The general idea is that jurors with average incomes will distrust a man who charges one-hundred-and-fifty or two-hundred-and-fifty dollars a day.

The cross-examiner, trying to be as unfair as possible, looks witheringly at the witness and says, "Doctor, you expect to be paid for your testimony in this case, don't you?"

That's the way I did it.

The witness who shifted his position, cleared his throat and started to explain was my meat.

---

* Presented at the Annual Meeting of the American Academy of Forensic Sciences, Feb. 28, 1957, Chicago, Illinois.

The question was framed so as to show that the witness expected to be paid for his *testimony*. As above mentioned, the question was deliberately unfair. Most cross-examiners don't want to be fair; they want to discredit the witness.

But every once in a while a smart one would look me in the eyes and say, "No!" and let it go at that.

Then, when I would be trying to recover from the shock and, before I could quite ask the next question, the witness would say, "I expect to be paid for the *time* I have spent in research and for the *time* I am *forced* to put in the courtroom. I *never* take pay for my testimony."

It was then up to me to either ask him about what he expected to charge for his time, or quit. If I asked him about the value of his time, the smart witness would smile at me, turn to the jurors and explain that his time had to include his overhead, the cost of maintaining his office, his books, his telephone, his secretary, the purchase of new machines or instruments, and the purchase of new books.

Then, still facing the jurors, he would say, "For instance, recently I installed a new machine," and then he would go on and start describing the machine, what it would do, the reason for it, how it worked. I was, of course, at liberty to stop him and I had to stop him because with every word he was selling himself to the jury. But when I stopped him the jurors felt as though I had jerked a magazine out of their hands just as they were reading the most interesting installment of a continued story.

Jurors are always interested in gadgets and a good expert witness can describe something as simple as a diathermy machine in terms of what it is expected to accomplish, and how it does it, so that the jurors will be following him with rapt interest.

If I couched questions in the technical terms I had so painstakingly looked up in the medical dictionary the expert would explain those terms to the jurors before answering the question. If I asked the doctor about a traumatic ecchymosis, he'd turn to the jury, say with an amused smile, "A traumatic ecchymosis is simply a bruise" and then answer the question.

The witness would always be courteous to me, but he'd always explain my technical terminology to the jurors and,

while he was about it, explain his opinions and conclusions and his reasons for reaching them. And he'd keep the jurors so interested they hung on his words.

We've heard a lot lately about demonstrative evidence. The lawyer puts things on a blackboard. He draws diagrams. He keeps the jurors interested. The good expert is the one who makes a verbal blackboard to illustrate his testimony. The expert should bear in mind what lawyers have discovered they can do with demonstrative evidence and keep his verbal blackboard in mind whenever a question is answered.

The doctor who would let me question him, using the words I'd so carefully looked up in the medical dictionary, and reply in similar terms, and talking to me instead of the jurors, was my meat.

The jurors would hear the technical terminology going back and forth. They wouldn't know what we were talking about, but they'd say to themselves, "That lawyer knows as much as the doctor."

The doctor who twisted and squirmed and let me get him on the defensive as he tried to justify his expert medical fees for courtroom appearance was duck soup. I would make it appear he was getting such a high fee it amounted to selling his testimony, yet indicate to the jury that he was selling out pretty cheap at that.

The doctor who cheerfully explained what went into his office overhead in terms of specifically describing some new gadget he'd bought and why it was used and what it would accomplish was selling himself all the time he was justifying his fees. He'd already done my side of the case plenty of damage on his direct testimony, so he'd gladly smother my cross-examination beneath a barrage of words about anything he felt would interest the jurors.

Rancho del Paisano
Temecula, California

Book Reviews

PRACTICAL FORENSIC MEDICINE, by Francis C. Camps, M.D. and W. B. Purchase, C.B.E., M.B., D.P.H. The Macmillan Co., New York, 1957, 541 pages.

As stated in the preface, the purpose of this new book is to assist the doctor or any other person who wants to know his position in a medicolegal case. With this goal in mind the authors have succeeded to produce an easily readable, well-illustrated outline of forensic medicine, with emphasis on the most common problems as they may confront the medical practitioner when coming in contact with medicolegal situations. There is no doubt that perusal of the pertinent chapters—and this includes an excellent list of poisons arranged as to: Nature and Use, Symptoms, Fatal Dose, Cause of Death and Fate in Body, Post Mortem Findings and Material to be collected for analysis —conveys in concise form vital information. Based on it an intelligent preliminary investigation can be initiated, obvious mistakes will be avoided and special laboratory methods of forensic pathology, toxicology and criminology, as suggested in the outline, can be started without undue loss of time or irreplaceable material. However, two factors seem to detract from the book's value: (1) The alphabetical arrangement of the different topics is only a poor substitute for a detailed general index. (2) The authors stress exclusively the English laws and regulations which are often at variance with those in force in the different states of this country. Because of the second factor, this book should be used, and will be of great value as a correlative text, in conjunction with other books on legal medicine.

K. E. Lande, M.D.

FORENSIC MEDICINE, by Douglas J. A. Kerr, M.D., D.P.H., F.R.C.P. (Edin.), F.R.S. (Edin.), Regius Professor of Forensic Medicine in the University of Edinburgh. A. & C. Black, London, 6th Edition (distributed in the U. S. A. by the Macmillan Co., N. Y.) 1957. Pp. XII, 363, $6.50.

The appearance of a new edition of Professor Kerr's well known small text-book is always a happy event. It is a lucidly and succinctly written outline of a broad field and admirably fulfills its designated function as a manual for medical students and a guide to the medical practitioner who has occasional medicolegal questions requiring a definite and reliable answer.

The two initial chapters as well as certain parts of the sections dealing with insanity, criminal responsibility and toxicology are concerned with the legal practices and regulations of England and Scotland. For the American

student this information is interesting but of little practical value. It is desirable in the case of students to be able to recommend a single book in which can be found the essentials of all of the subdivisions of forensic medicine. This relative defect could be remedied by reverting to the older practice of having these portions of the subject matter written by an American expert or at least added in the form of an introduction or appendix.

The expression, at least parenthetically, of measurements in metric units would also be more in keeping with the current teaching and practice in this country.

Certain authors are referred to by name but there is no true bibliography or list of references and sources. This makes for brevity but it appears that those for whom the book is primarily intended are likely to be most in need of guides to further reading.

Under the brief discussion of the medicolegal autopsy there is no mention of the importance of removing *en bloc* the organs of the neck. This procedure of course is a very important and essential feature of this specialized postmortem examination, even though some form of mechanical asphyxia is not suspected.

There is introduced a new method for estimating the time of death using the "virtual cooling time." The method is reported to have been used with excellent results in Professor Kerr's department and acknowledgment is made of the assistance of Doctors Fiddes and Patten in developing it. On the basis of the brief discussion presented, this appears to be a useful aid in approaching one of the most vexed problems in all forensic medicine. However, before acceptance is unreserved it would be desirable to see a reference to a journal article or monograph setting forth the figures and other experimental data used to establish the procedure. No such references are found.

Some of the sections are quite brief and do not mention recent work tending to clarify certain problems. For example, air embolism is mentioned only in passing as a danger of criminal abortion. Likewise, fat embolism is mentioned only as a possible cause of duodenal ulceration after severe burning. No mention is made of the stimulating work of Schwann and associates on the physiologic and biochemical phenomena associated with drowning in fresh water or sea water; nor is notice taken of the recent work done in the use of specific gravity readings on the plasma from the two sides of the heart as an aid in the diagnosis of death from drowning. Under the discussion of examination of seminal stains, only Florence's test is mentioned. No reference is made to the value of acid phosphatase determinations in this connection.

There is a short chapter on the historical development of forensic medicine, but the chronology stops rather abruptly in the early Nineteenth Century. Certainly any such discussion, if presented at all, should be carried into more modern times. Alfred Swaine Taylor, Johann Ludwig Casper, and the great contributions of the Germanic schools prior to World War I as well as later French contributions, including the work of Tardieu and Brouardel, are worthy of enumeration.

Photographs are fairly numerous and are in general well reproduced and illustrative of basic points. A number of useful line drawings are also in-

cluded. There are presented two "natural colour" photographs of the stomach in lysol poisoning and hydrocyanic acid poisoning. Actually the colors are muddy shades of black and red and these plates are not up to the standard expected from the Edinburgh school. They should be withdrawn or replaced in subsequent editions.

Some of the foregoing criticisms are merely captious and none indicates a major defect. Obviously this book represents the distillate of much practical experience with a minimum of armchair speculation. The uncritical repetition of traditional medicolegal dogma and classical fables is minimal. The book is a happy compromise between a mere quiz compend and the more elaborate reference works. The price is reasonable and the book can be well recommended as a guide to medical students and the nonspecialist practitioner. Even the expert will find here a ready and useful review for his working library.

Richard O. Myers, M.D.

AN INTRODUCTION TO TOOL MARKS, FIREARMS AND THE STRIAGRAPH by John E. Davis, Criminalist in Charge, Criminalistics Section, Oakland Police Department, Oakland, California. Charles C Thomas, Springfield, Ill., 1958. Pp. 282, $7.50.

After reading the first seven chapters, one feels that the author, perhaps for brevity's sake, failed to give an adequate title to his work. The word "Identification" seems to be missing, but this will not mislead the initiated.

While Tool Marks and Firearms Identification are introduced with tedious thoroughness covered by most texts, the author quickly passes to subject matter often neglected or lightly touched upon by most writers. He treats the problems encountered in identification work, and candidly discusses the difficulties of reaching a positive conclusion under certain conditions.

The author discusses efforts to establish the class characteristics of the bore of the weapon through measurements of the various elements of the fired bullet. In this he separates theory from the practical aspects, by treating in detail difficulties in instrumentation and technique in this endeavor. He also discusses the application of the light profile microscope in revealing surface contour, and the limitations of this technique when applied to cylindrical specimens such as bullets. At this point one gets the impression the author is building a case for the valid and useful existence for his Striagraph.

The remainder of the text is devoted to detailed description of the development of the Striagraph and its application in Tool Marks and Firearms Identification work. The usefulness of this instrument in providing data in thickness testing, groove depths, groove widths and land heights from analysis of bullet striagrams is explained. The author also mentions that the application of this instrument in determining rate of twist with accuracy at least equal to that by present methods is feasible. The author further suggests other research by means of this instrument, but states that the development work was in itself so time-consuming that much of this had to be left for the future. It is apparent that this instrument will be of particular interest

to those engaged in research relative to interpretation of rifling data from fired bullets.

The Striagraph is essentially composed of a tracing and a recording mechanism. Tracings are recorded by the movement of optically amplified light on photosensitive paper.

Repeat striagrams of same specimens (presented photographically by the author) indicate the instrument is capable of consistent reproduction of surface tracings in fine detail. The author expressly states that the Striagraph is not intended to replace the comparison microscope technique for practical work, but will supplement investigation in many instances. As an example, general waviness of surface would be readily revealed, while under the microscope this might not be so apparent.

The thought that striagrams might be useful in demonstrating the basis for conclusions of identity in court of law is suggested. It certainly seems reasonable that if a striagram of the evidence and one of the test closely corresponding in detail were presented, they would be very convincing. However, individuals lacking specialized experience in this line of work would not be qualified to evaluate what they see, regardless of the extent of similarity present, that a positive conclusion of identity is warranted. There are also some legal aspects to be considered. It seems that the presentation of striagrams which are not absolutely true representations of the surface of the specimens would be objected to. Any increase in vertical or horizontal amplification to dramatize salient points might, for legal procedures, be considered unacceptable.

The text is fully illustrated with many photomicrographs, photographs of the instruments developed, and striagrams produced by the author. It is highly informative and deserves serious consideration by all engaged in the field of Tool Mark and Firearms Identification.

John B. Ascher

Modern Concepts in Investigation of Aircraft Fatalities*

*Frank M. Townsend, Col., USAF (MC),** and Vernie A. Stembridge, Maj., USAF (MC) ****

Travel by aircraft has now become our chief mode of commercial transportation. According to figures recently released by the Civil Aeronautics Board (1), U. S. Airlines flew 26.3 billion passenger miles in 1957 compared with an estimated 25.2 billion passenger miles for buses and 21.6 billion passenger miles for railroads. Airline passenger has risen uninterruptedly since its inception and has made large gains within the past few years. Flying is safe. During 1957, an estimated 45 million persons were flown about 26.3 billion passenger miles with only 31 fatalities, or a fatality rate of 0.2 per 100 million passenger miles. (The National Safety Council estimates that automobile fatalities were at the rate of 2.7 per 100 million passenger miles.) In 1956, 41 million people were flown 23.2 billion passenger miles with 143 fatalities. The military experience similarly indicates that flying is safe, for only a minute number of flights end as an accident. For every 1000 flights flown by the U. S. Navy in 1955, 999.32 had no mishap; and during 1957 this figure was 999.44 per 1000 flights (2). The U. S. Air Force has experienced 999.79 landings in 1000 without an accident and 999.64 flying hours per 1000 without an accident.

---

* Presented at the Tenth Annual Meeting of the American Academy of Forensic Sciences, February 28, 1958, Cleveland, Ohio. Received for publication February 28, 1958.

** Deputy Director, Armed Forces Institute of Pathology, Washington, D. C.

*** Section Forensic and Aviation Pathology, Armed Forces Institute of Pathology, Washington, D. C.